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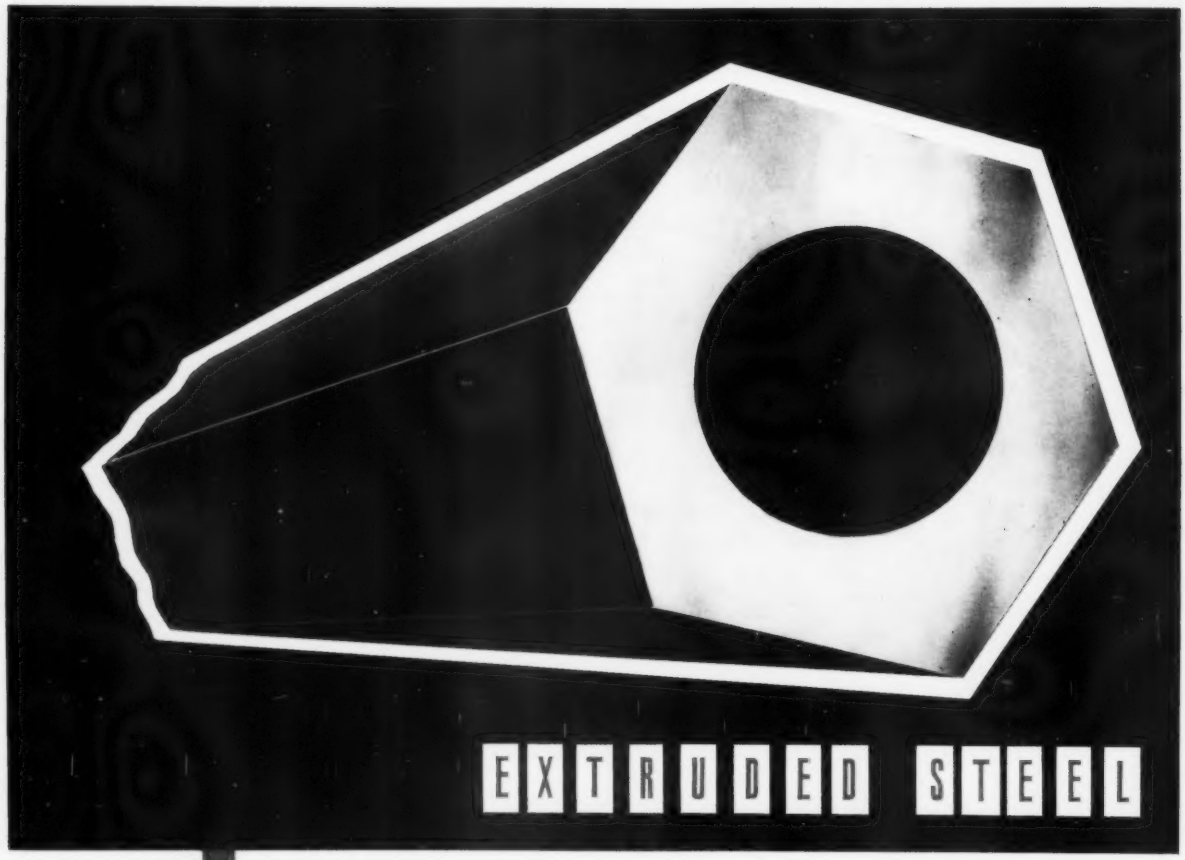
Atomic energy in the Federal Republic of Germany

pp 58-97

March 1961 monthly 3/6



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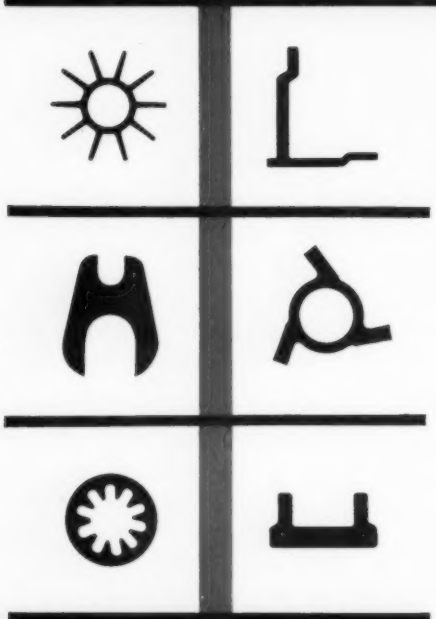

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COVER PICTURE

Map shows nuclear installations in the German Federal Republic.

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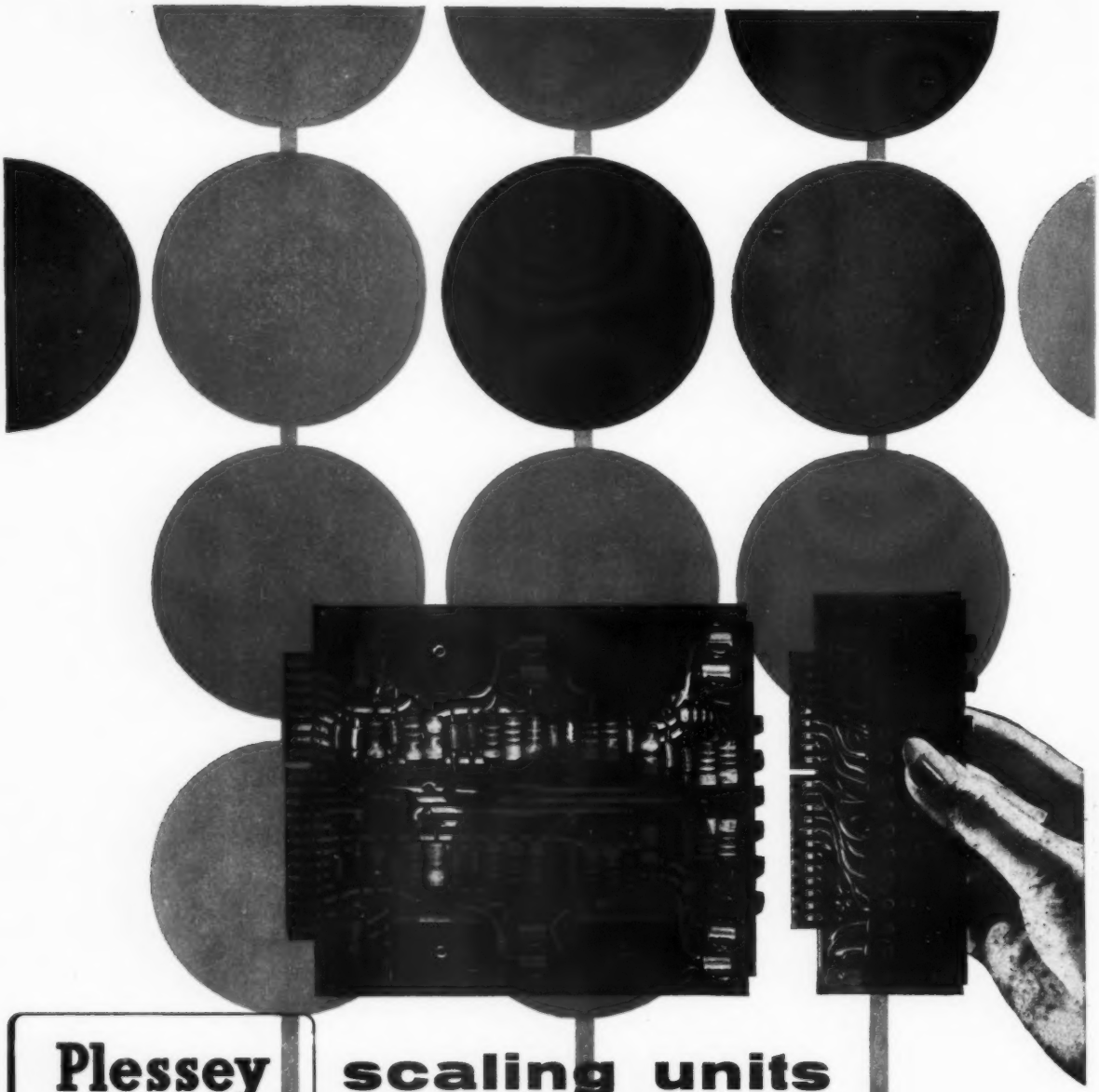

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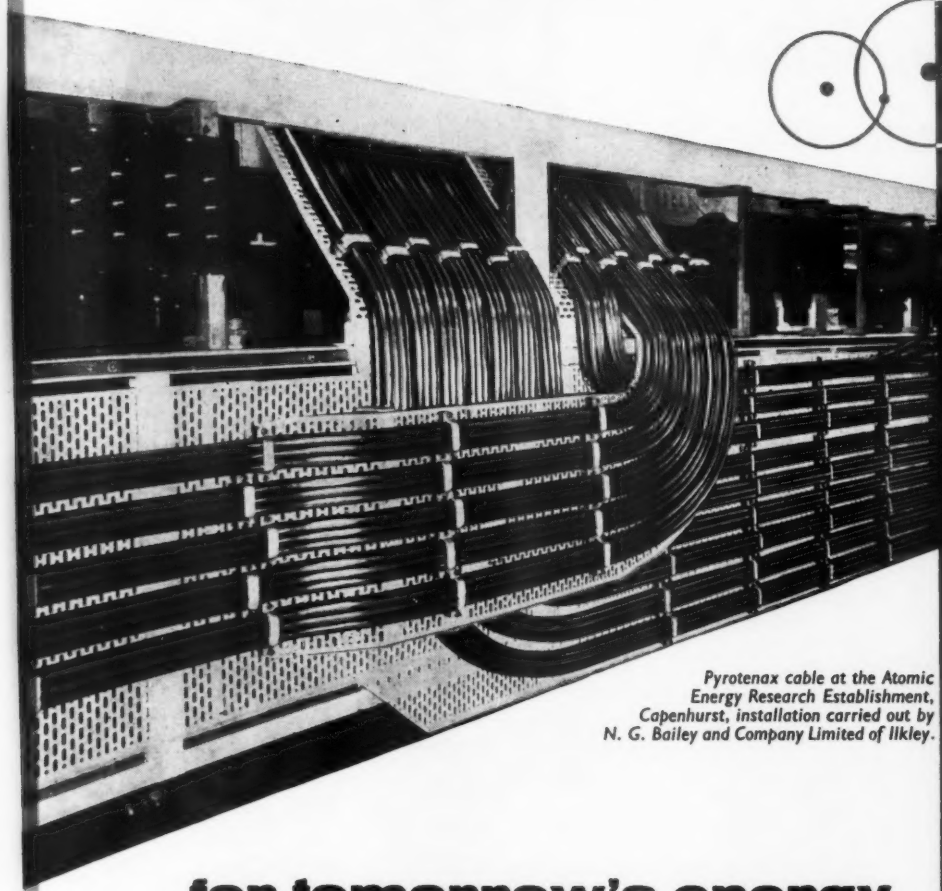

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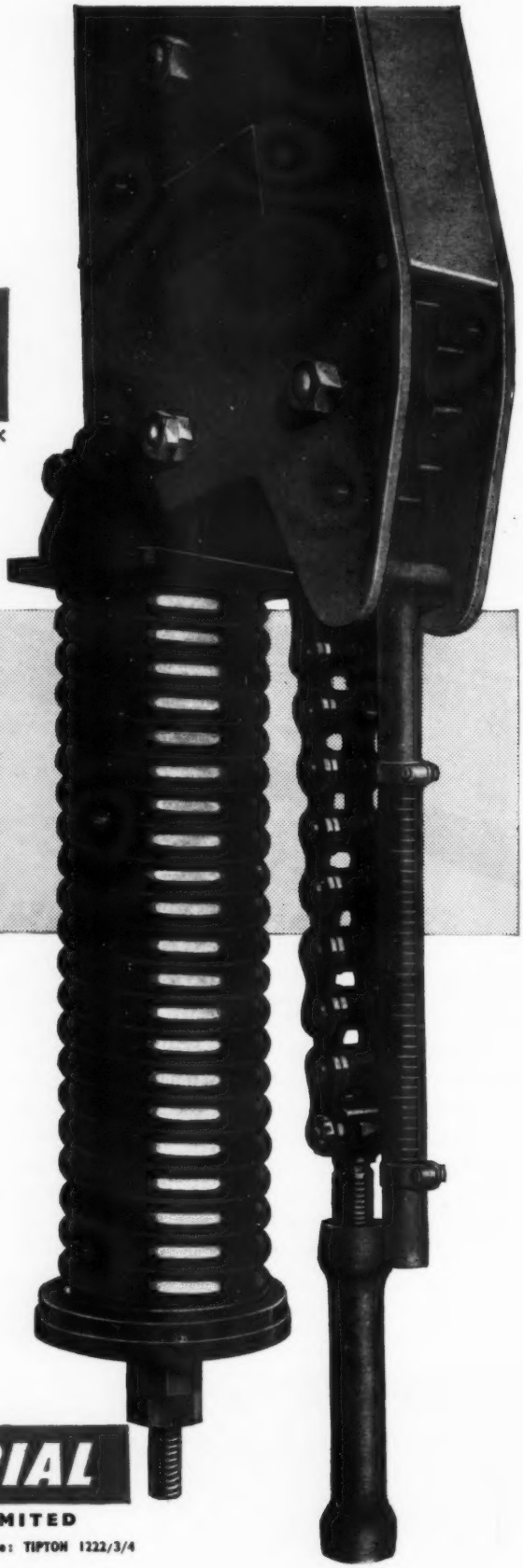

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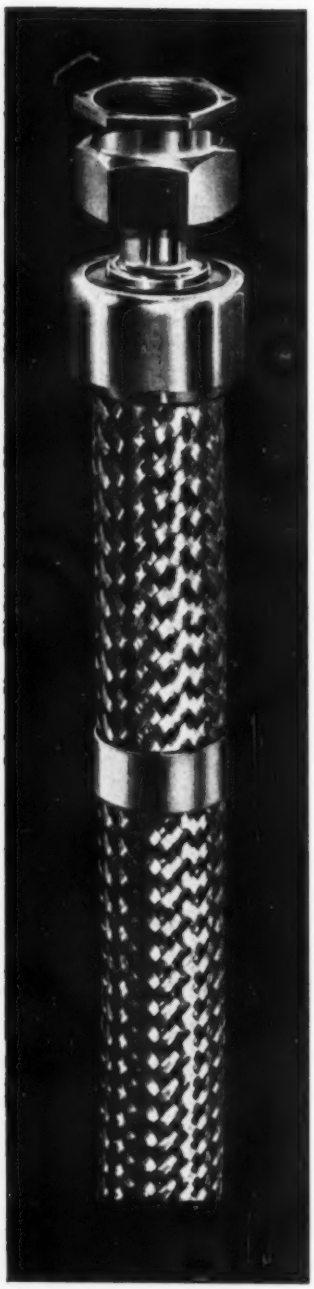

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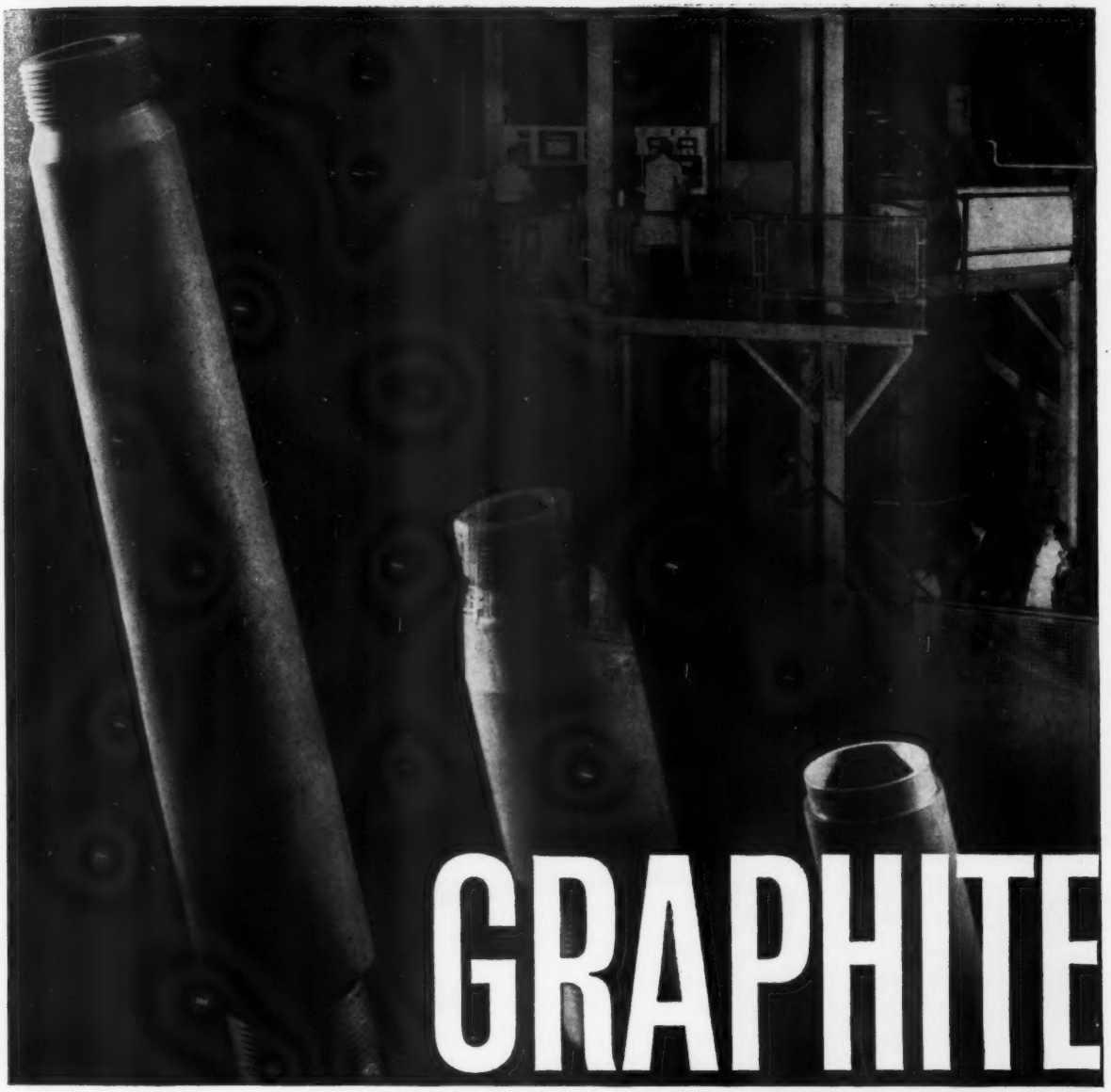

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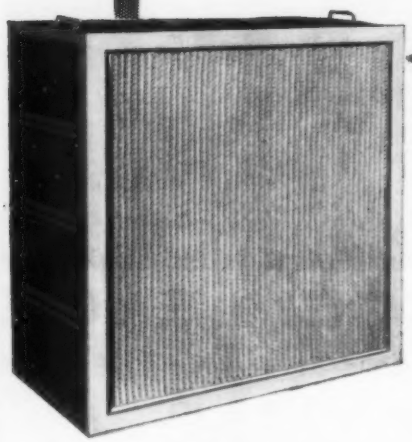

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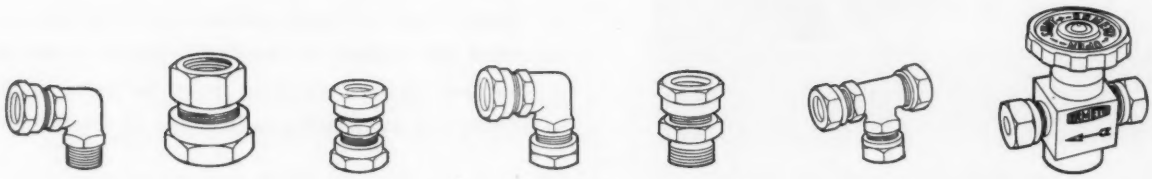

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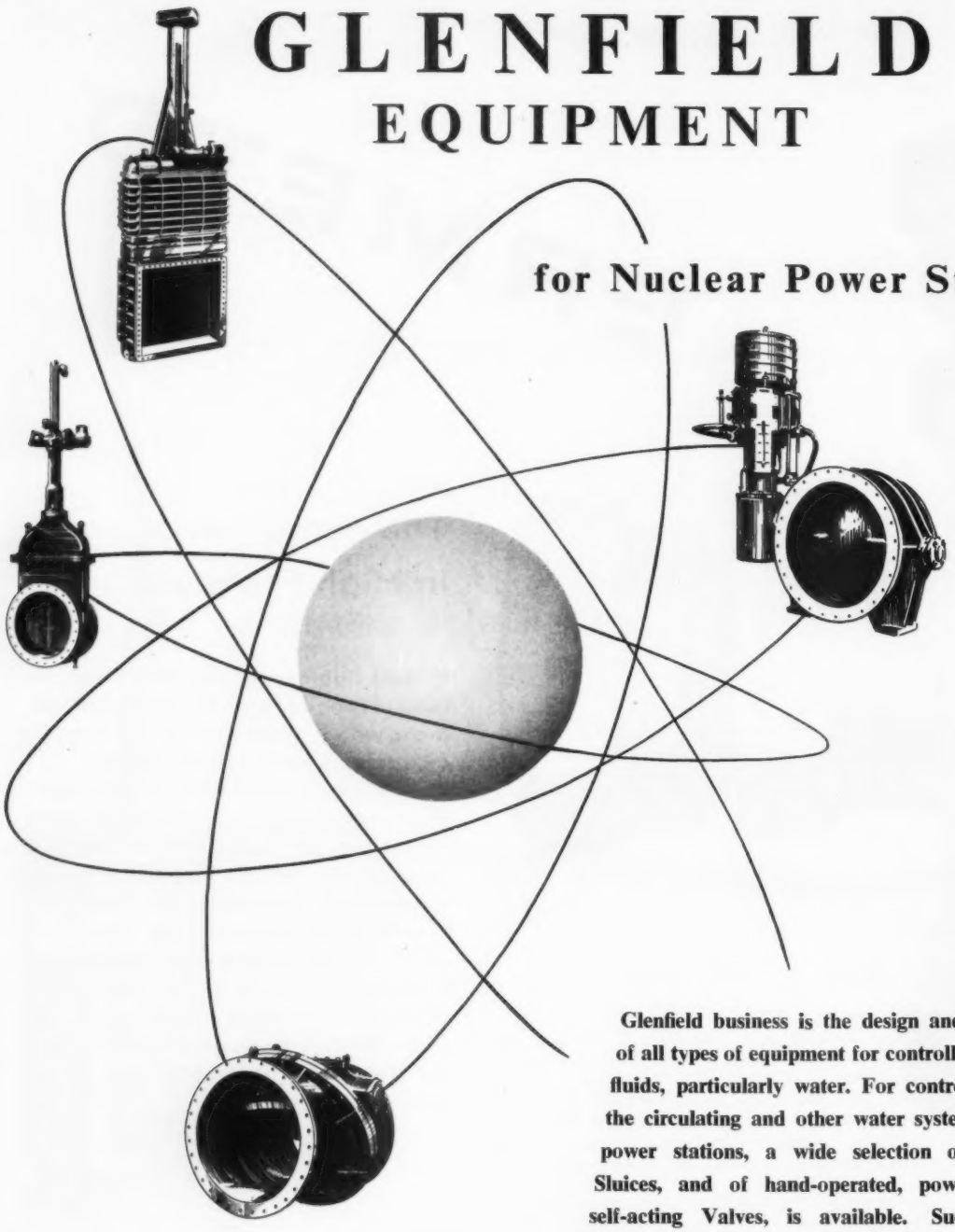

Glenfield business is the design and manufacture of all types of equipment for controlling the flow of fluids, particularly water. For control purposes in the circulating and other water systems of nuclear power stations, a wide selection of single-faced Sluices, and of hand-operated, power-driven and self-acting Valves, is available. Such equipment has been supplied, or is on order, for many of the stations now in operation or in course of construction.

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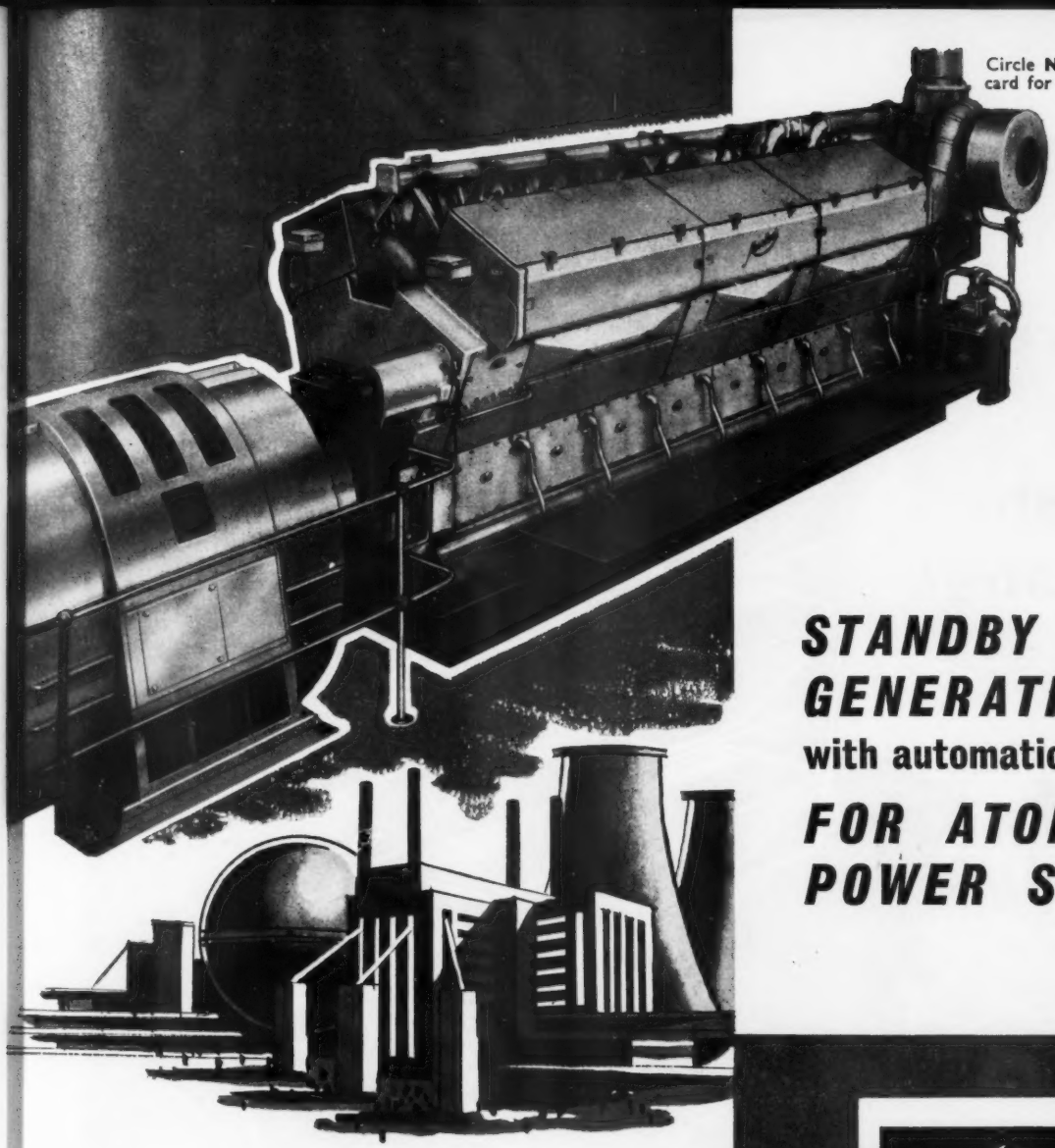

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with automatic starting
FOR ATOMIC POWER STATIONS

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The power range extends from the 210 BHP J3 three-cylinder naturally aspirated up to the 2272 BHP JVSS 16 sixteen-cylinder turbocharged engine with air aftercooler.

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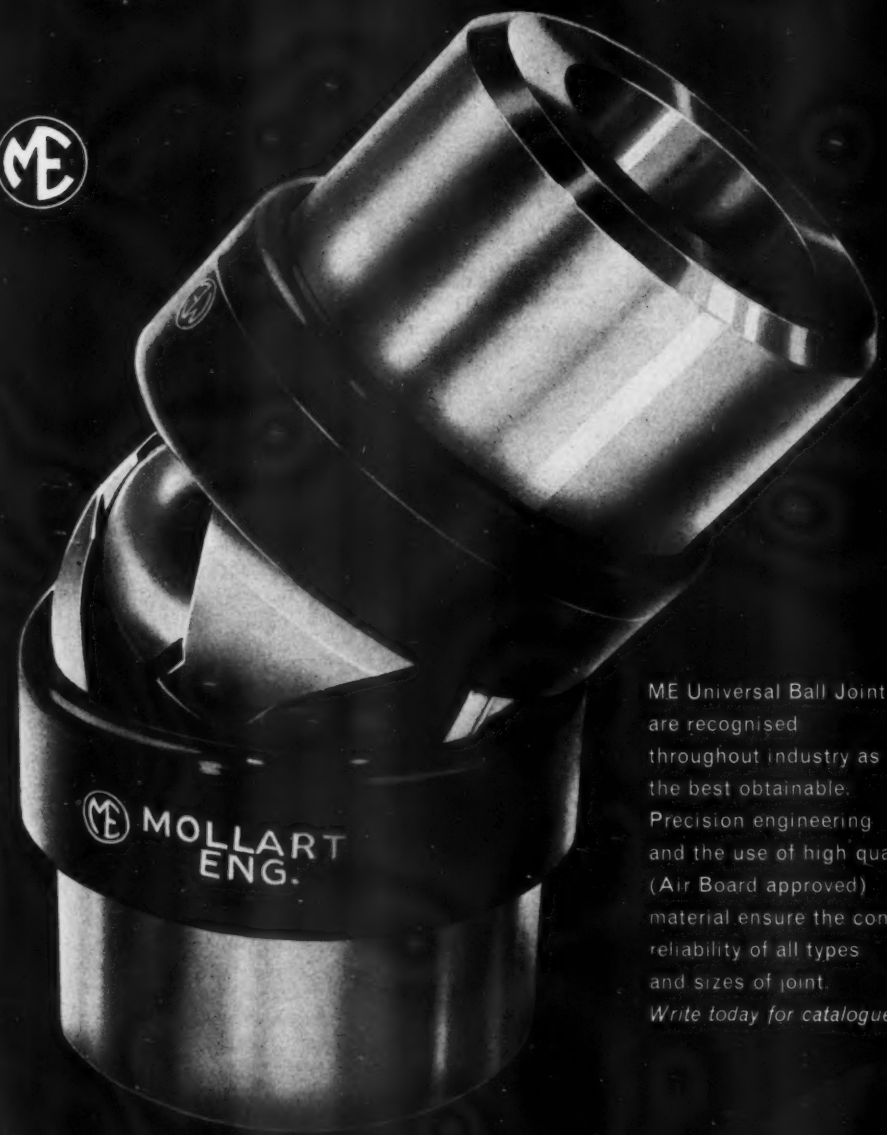

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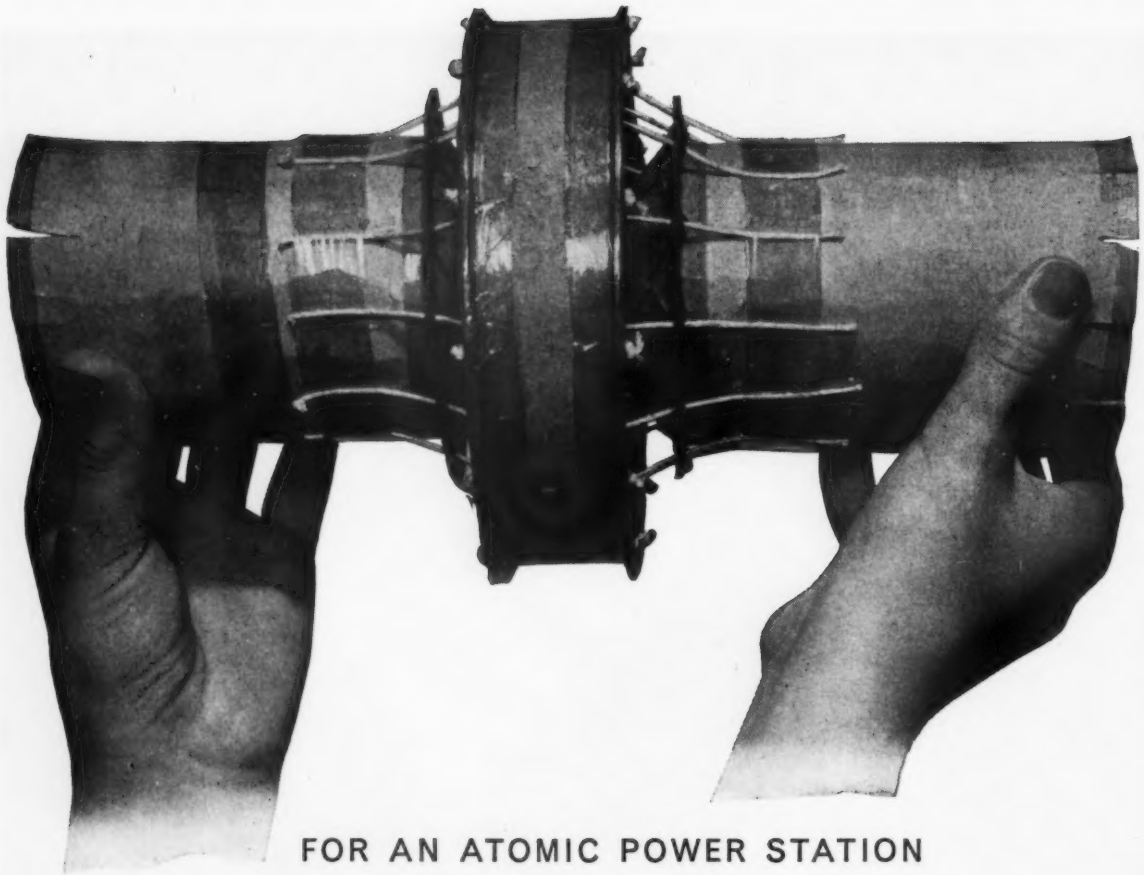
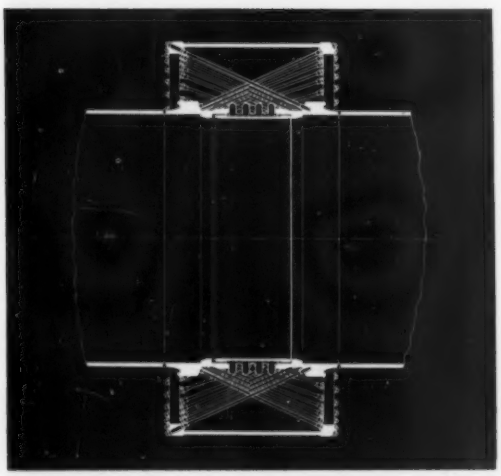


FOR AN ATOMIC POWER STATION



Don't despair if you cannot immediately follow the functioning of the bar system. It took the Engineering Division several days to understand it, and the only way they could make it clear to our executives was with the cardboard model in the photograph.

With cardboard, string, the office sticky-tape and an artificial pearl borrowed from a typist (for the spherical joint between the two cones) Richardsons Westgarth engineers have knocked up a radically new solution to a very old and tricky problem – how to take up the expansion of large pipes carrying high pressures. The problem came into the design office in the specific form of the CO_2 ducting of the Trawsfynydd Atomic Power Station. Pressure 265 p.s.i.; temperature 420°C; axial thrust on any cross section over 1,000,000 lb.

The usual means of taking this thrust – on either an internal flexible tongue or an external arrangement of hinge pins, guides and rollers – are cumbersome and, worse, flexible in only one plane, so that any sideways deflection produces stresses incapable of analysis. Rollers and pins need lubrication and are subject to wear, and both disturb the uniform distribution of stress around the periphery of the pipe. In the new Richardsons Westgarth joint the end restraint is provided by a ring of high-tensile steel bars, and flexing is taken entirely by elastic stress in these bars. The joint is thus flexible in *all* directions. No lubrication is needed; all forces are calculable – and they are fed uniformly onto the periphery of the restraint.

This is the kind of solution – unconventional, simpler, sounder and cheaper – that the fresh thinking of Richardsons Westgarth engineers is continually producing.

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At Britain's latest nuclear power station at Trawsfynydd, as in so many other projects, Fairey are there . . . at the heart of things. They are at work on a major programme of research, development, design and manufacture for nuclear power stations and experimental establishments throughout the country. Fairey have been thinking and living nuclear engineering for years—they know what they're about.
Fairey's nuclear work includes: U.K.A.E.A. experimental reactor equipment, power reactor equipment, fuel element cans, controlled thermonuclear research equipment, aluminium and steel fabrications nuclear fuel processing equipment, plastics and plastics fabrications, electronics and special instrumentation, machine tools and remote handling equipment, hydraulic equipment and gas filters.

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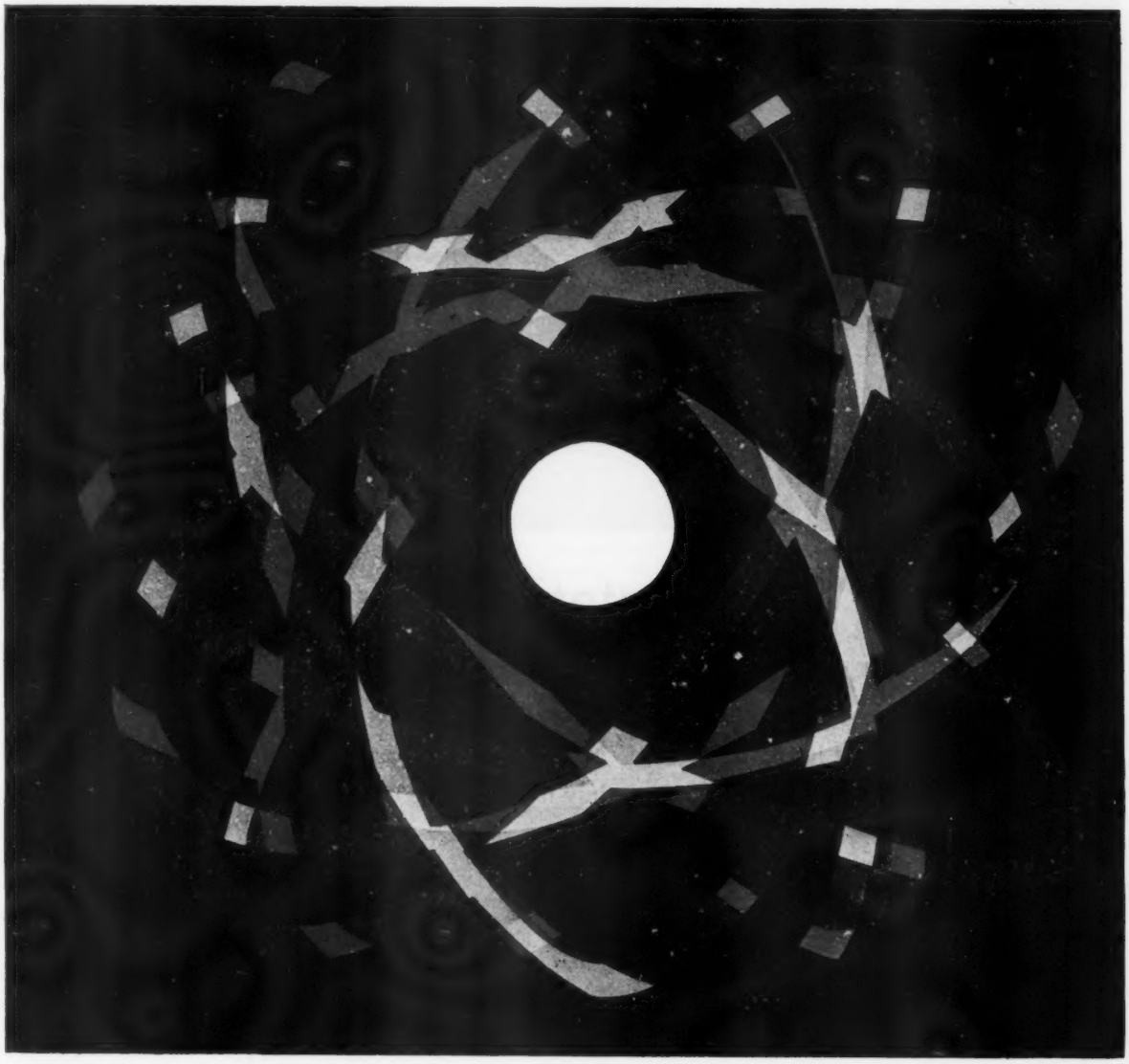

the Joy WN112 stationary compressor

Engineers right on their toes designed the Joy WN.112 compressor, designed it for balance, high-stepping efficiency and the quick precision of a ballet movement. The faultless timing, alignment and complete harmony of the WN.112 make it a machine well worth studying— write for a copy of Publication AD/6 – study it well.

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raised the roof
Fabrications in unusual shapes and sizes are Marston's speciality — fabrications like this aluminium brass end seal for a heat-exchanger at the National Gas Turbine Establishment.* It was so big that we had to remove part of the roof in one of our erecting shops — but that kind of thing is all in the day's work for us. If you're contemplating engineering, chemical petroleum or nuclear power plant that calls for components to unusual specifications, consult us at the design stage: our experts can contribute much to the smooth, speedy and economical execution of your plans.
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in aluminium, titanium and other non-ferrous metals.
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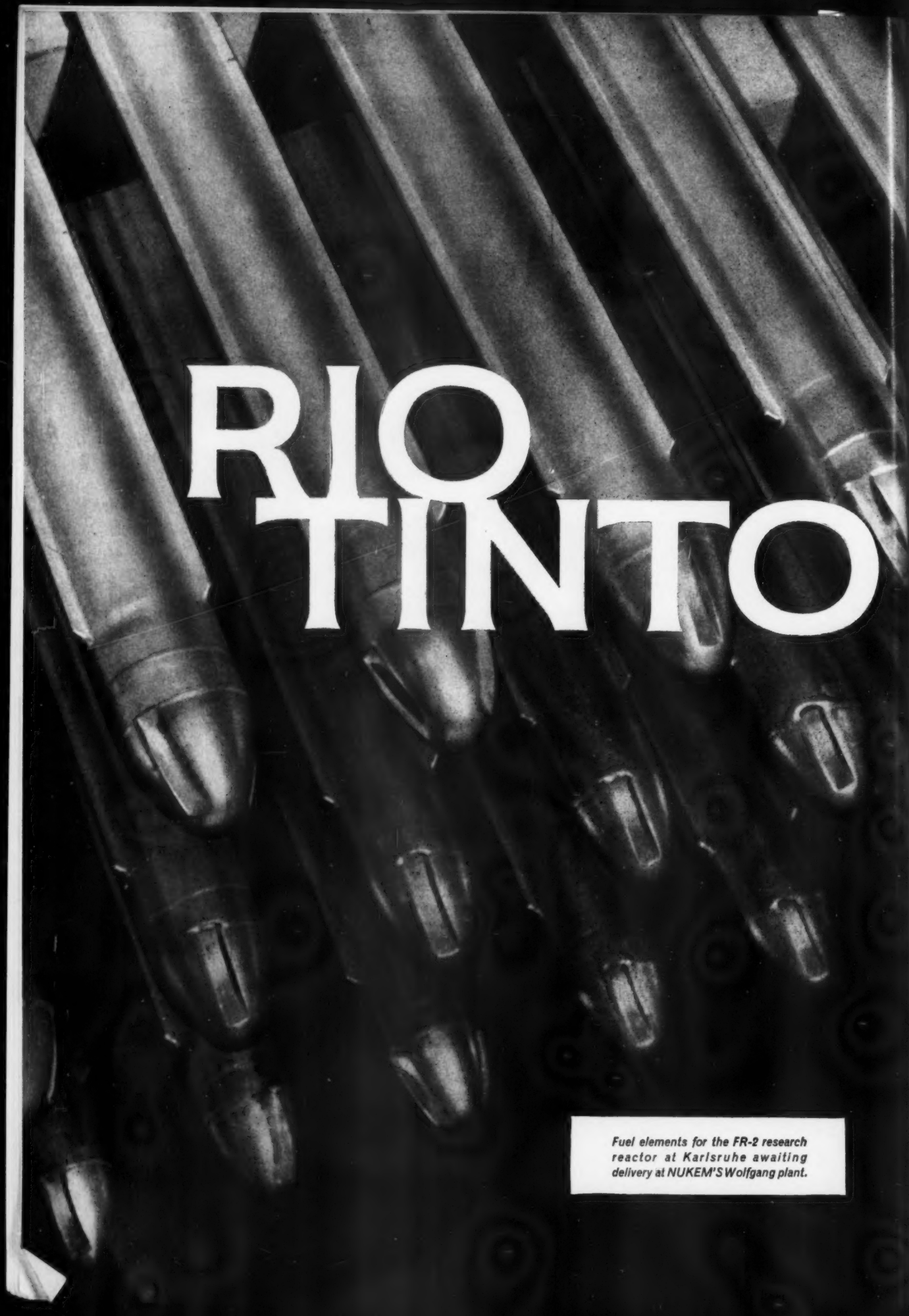
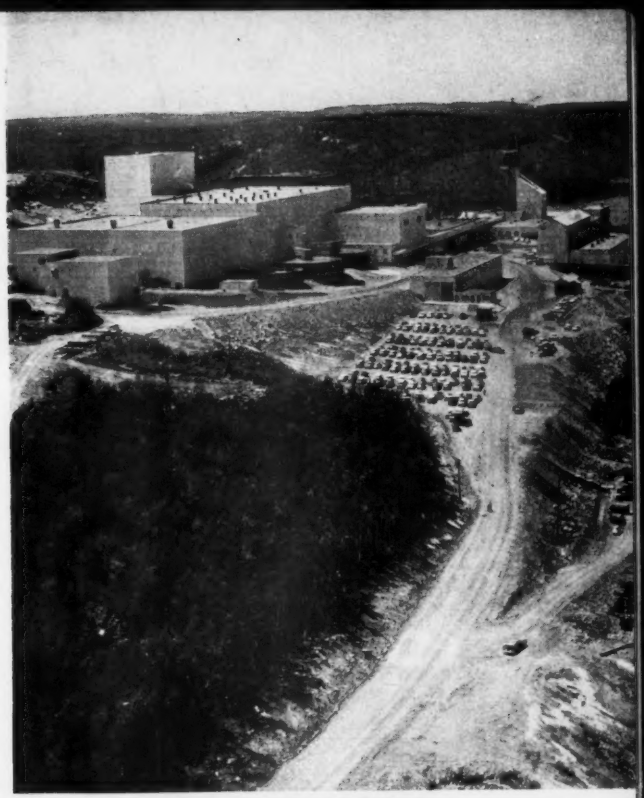


Fuel elements for the FR-2 research reactor at Karlsruhe awaiting delivery at NUKEM'S Wolfgang plant.



The 3,000 ton per day Nordic uranium concentrating plant of Rio Algom Mines Limited, Canada.

IN EUROPE

Rio Tinto has joined forces with the leading German metallurgical group, Deutsche Gold- und Silber-Scheideanstalt vormals Roessler (Degussa), to form NUKEM—Nuklear-Chemie und -Metallurgie Gesellschaft m.b.H.

NUKEM has taken over the research and production programme of the Degussa Nuklear Gruppe, covering a wide range of uranium and thorium processing and fabricating activities related to the nuclear power programmes of a number of countries.

NUKEM is co-operating closely with Rio Tinto's Canadian uranium mining interests and with Rio Tinto Dow Limited, a company specialising in uranium and thorium processing.

Nukem—Nuklear-Chemie und -Metallurgie Gesellschaft m.b.H., Wolfgang bei Hanau (Main)
Rio Tinto Management Services (U.K.) Limited, Barrington House, 59, Gresham Street, London, E.C.2.
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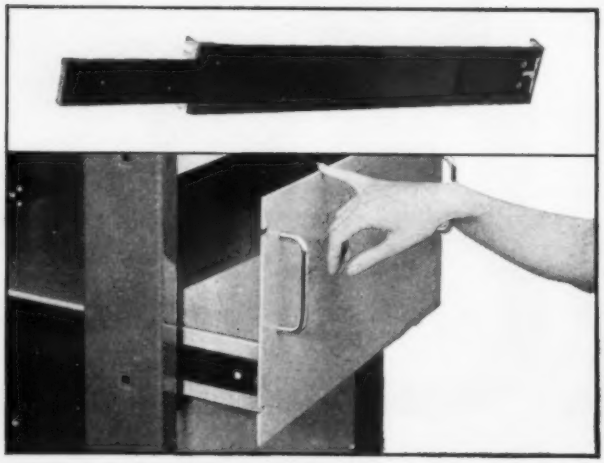
new single extension



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materials high tensile strength aluminium alloy with black anodised finish. Pins, bearings etc., of chrome steel, cadmium-plated carbon steel or stainless steel.

lightness a pair of IMS 300/24 runners weigh 3lb 10oz (1.64kg) as against 6lb (2.72kg) for a pair of conventional runners.

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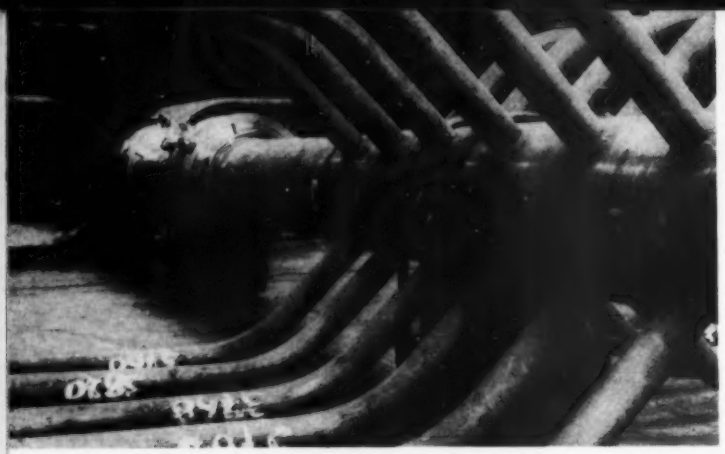

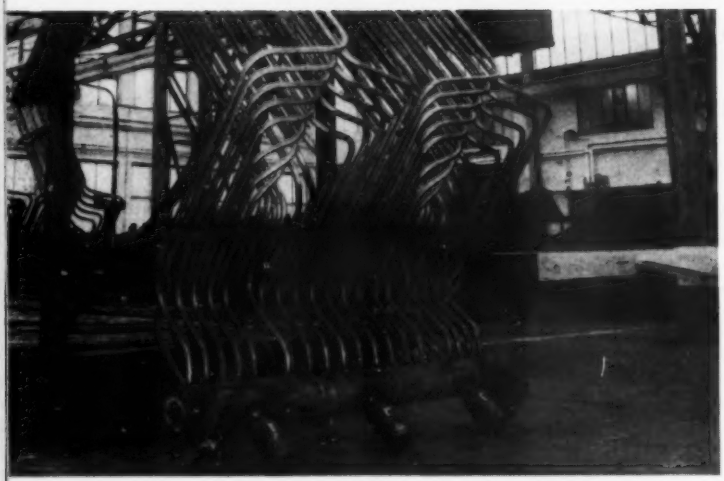

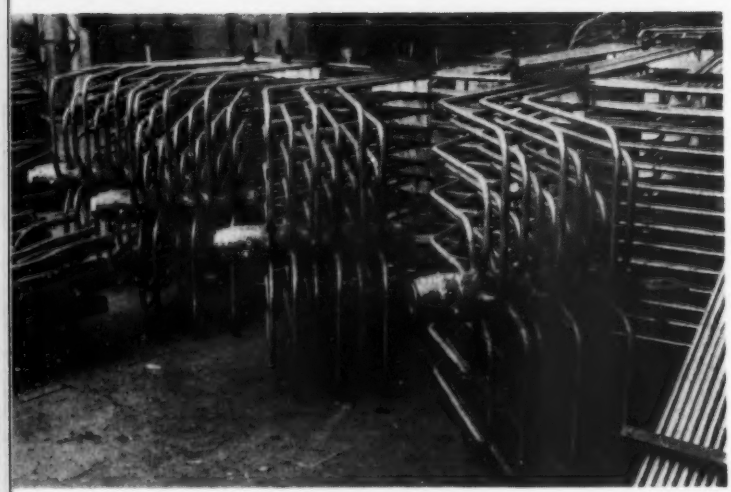

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Steam Generators with austenitic Superheater tubes

are built by **DÜRRWERKE AKTIENGESELLSCHAFT** as part of their production programme. For fourteen (14) high-capacity steam boiler plants with steam conditions of up to 1200°F and 4850 lb/in² there were used some

492,000 ft of tube 20 - 30 mm outside dia., 3.5 - 6 mm wall thickness;

10,000 ft of tube 63.5 - 121 mm outside dia., 7 - 12 mm wall thickness;

2,000 ft of tube over 130 mm outside dia., 16 - 40 mm wall thickness;

These tubes of the high-temperature resistant all-austenitic chrome-nickel steels x8 Cr Ni Nb 1613, x8 Cr Ni Mo ND 1616 and x8 Cr Ni Mo V Nb 1613 were manually welded by both inert-gas metal-arc and shielded metal-arc processes, for which new joint designs have been developed. To complete the fourteen boilers more than 31,500 welds within the pressure systems were made. Of these, butt welds on tubes with smaller wall thickness total some 15,000, on tubes with thicker walls some 1,500; the remaining 15,000 are tube-to-header joint welds.

DÜRRWERKE AKTIENGESELLSCHAFT ranks among the oldest companies in the field of high-capacity boiler design and construction. Founded in 1883 by Gustav and Walther Dürr, the company made at first single-chamber water tube boilers known as **DÜRR** Boilers, which rapidly found wide international acceptance, also in ship-building. Other remarkable steps in the company's initial development have been the construction in 1903 of the first **DÜRR** travelling grate stoker, the production of Garbe straight-tube boilers starting in 1907 and, along this line, the first vertical-tube boiler with 360 lb/in² operating pressure in 1915.

After in 1924 the company's name had been changed into what it is today, **DÜRRWERKE AKTIENGESELLSCHAFT** entered the second stage of its development in 1932 when building the first **DÜRR** "ultra high-pressure" boiler for 1660 lb/in² operating pressure and 172,000 lb/hr evaporation. In 1934, the manufacturing programme was extended to once-through Benson boilers, and in 1940 the first **DÜRR** pulverized coal firing system went into operation.

Another milestone in the company's history is the construction in 1950 of a Benson boiler with the world-record operating temperature of 1130°F. By 1956 over 4,000 **DÜRR** boilers had been built; and in 1959 the **DÜRR** low-load system for once-through boilers, which makes it possible to operate these units at any desired percentage of full load, was field-tested and has since been in successful use. By 1960 more than 100 **DÜRR** Benson boilers were installed or on order.

With this experience to rely on, and with its staff of expert personnel linked to the company over generations, **DÜRRWERKE AKTIENGESELLSCHAFT** is a highly qualified and dependable partner to co-operate with also in the construction of nuclear power stations. Field results from austenitic material in steam generating plants with more than 100,000 hours of operation are available for evaluation.

DÜRR WERKE AG

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Steam Boiler Manufacturers Since 1883

nuclear energy for ship propulsion

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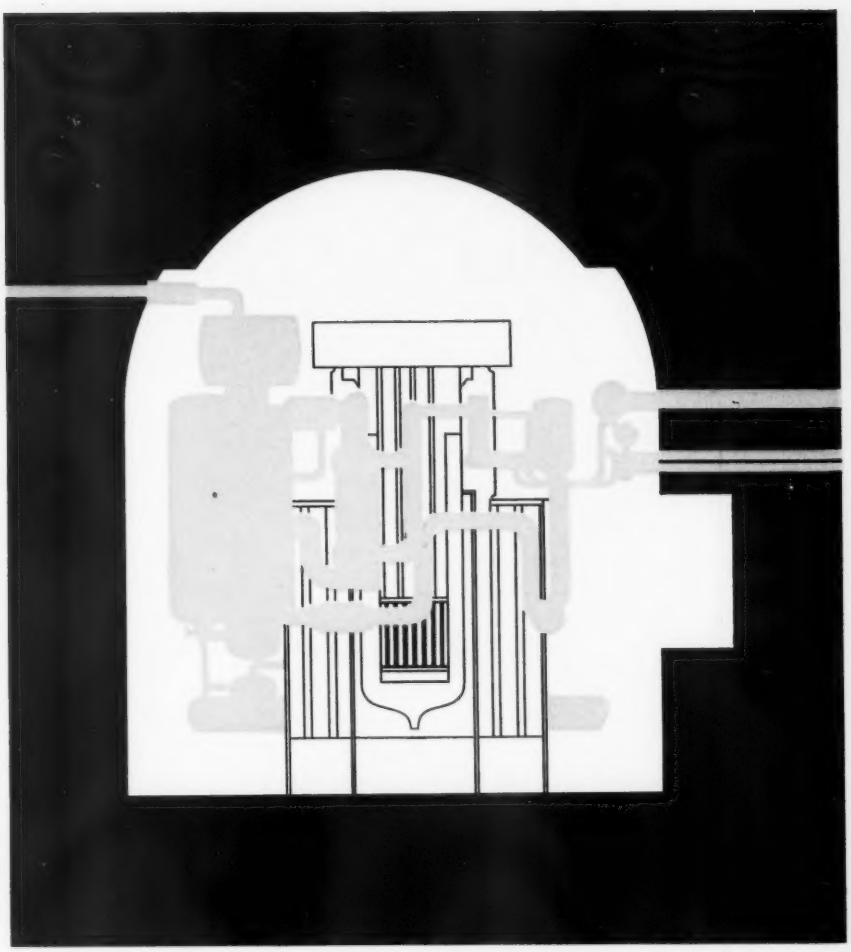

Containment and internals of a maritime reactor under development jointly with GKSS and EURATOM

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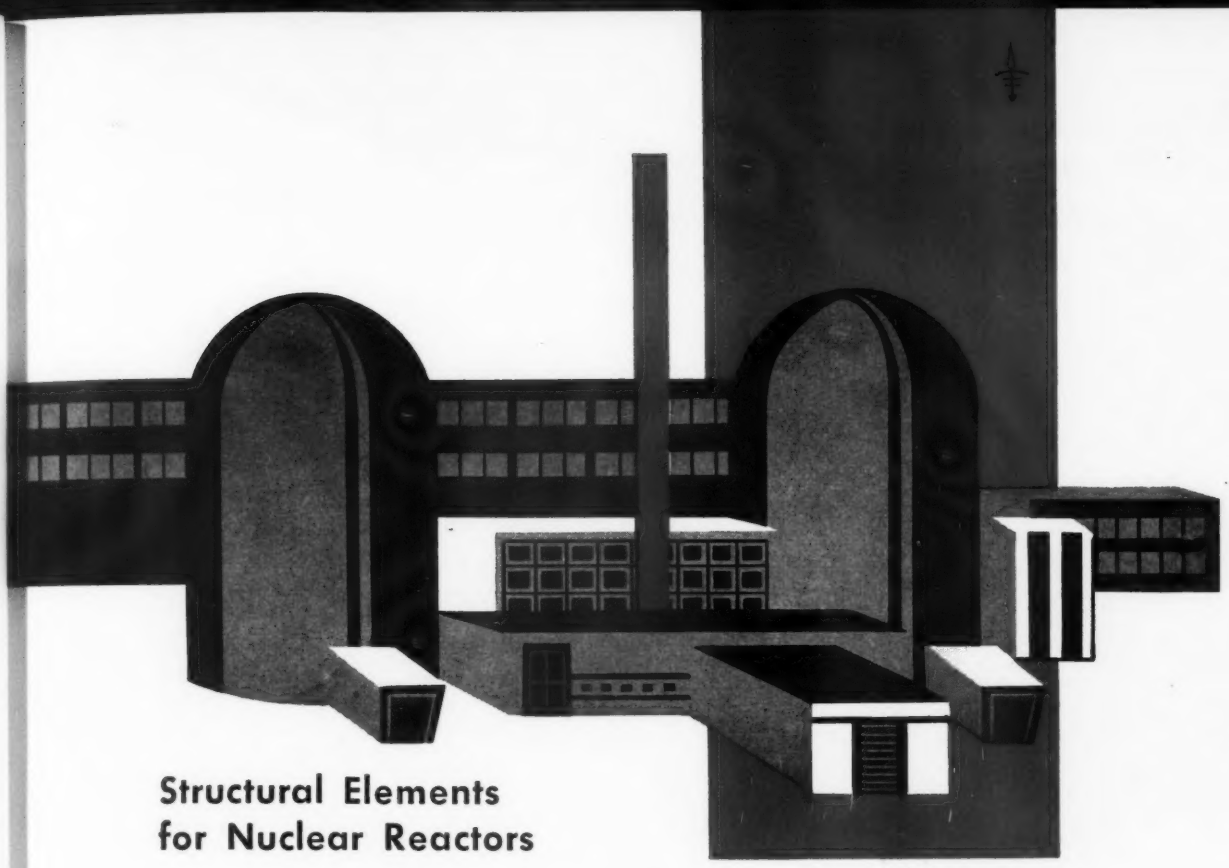

Structural Elements for Nuclear Reactors

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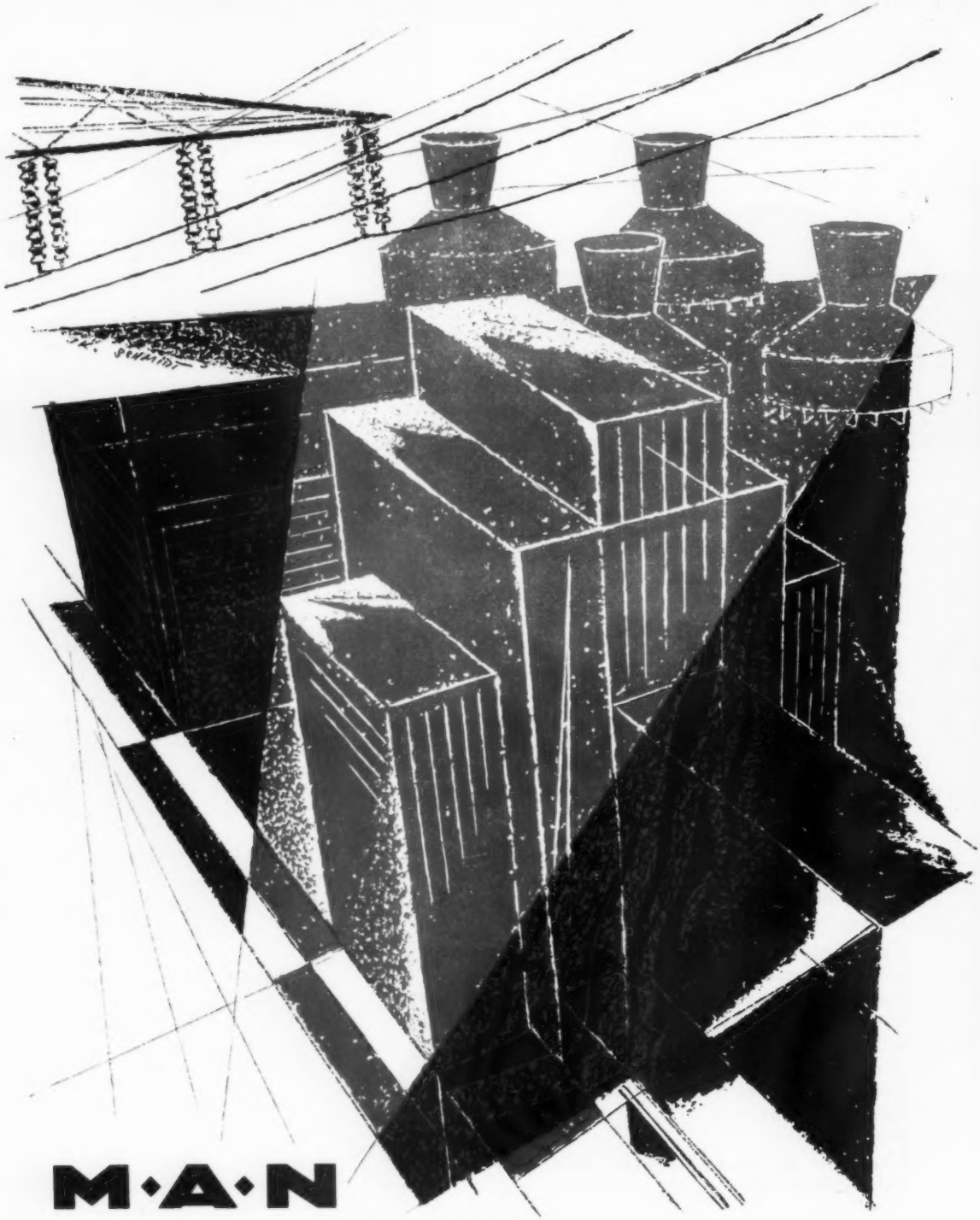

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design and build

Nuclear Power Stations

in close cooperation with
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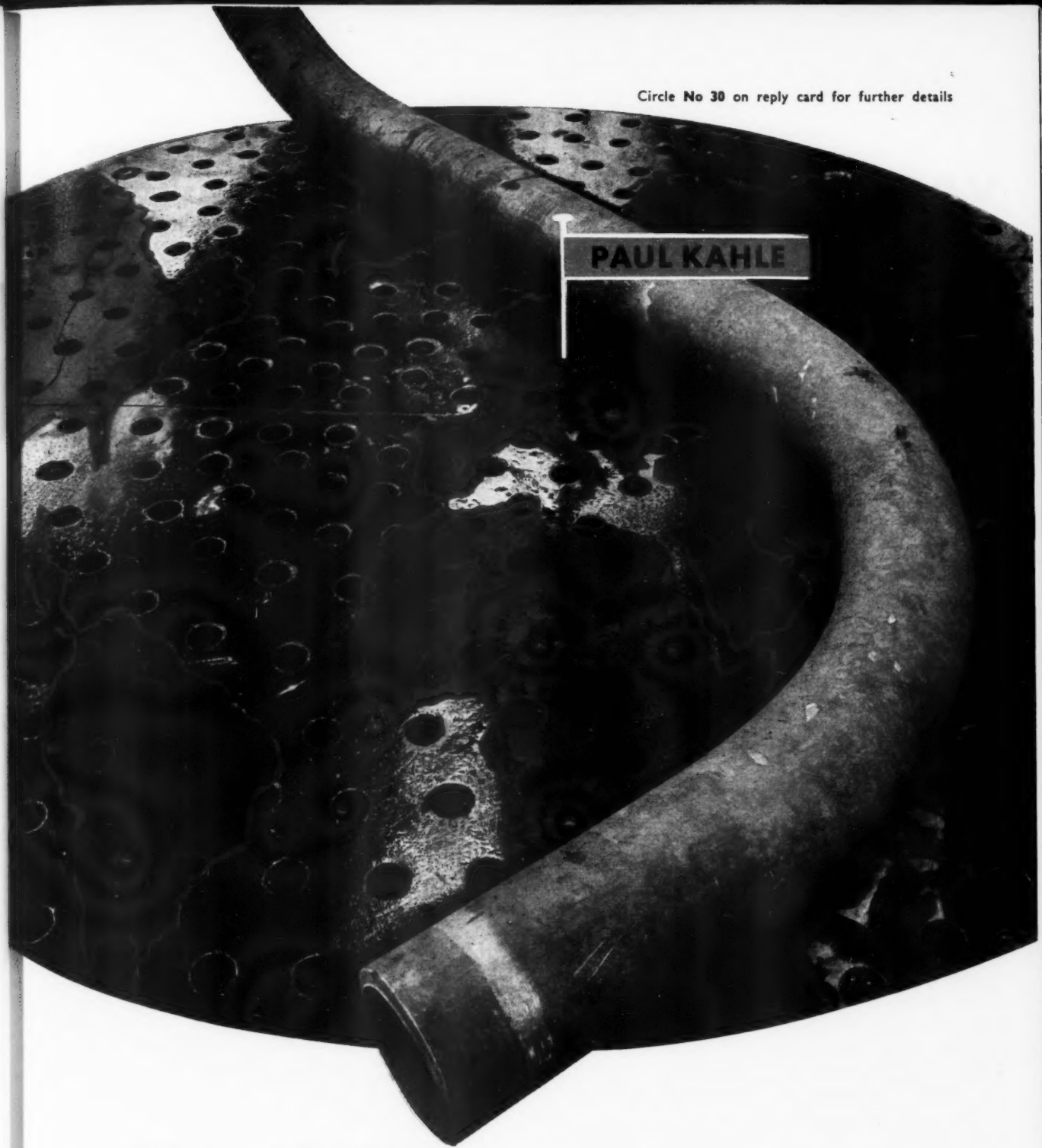

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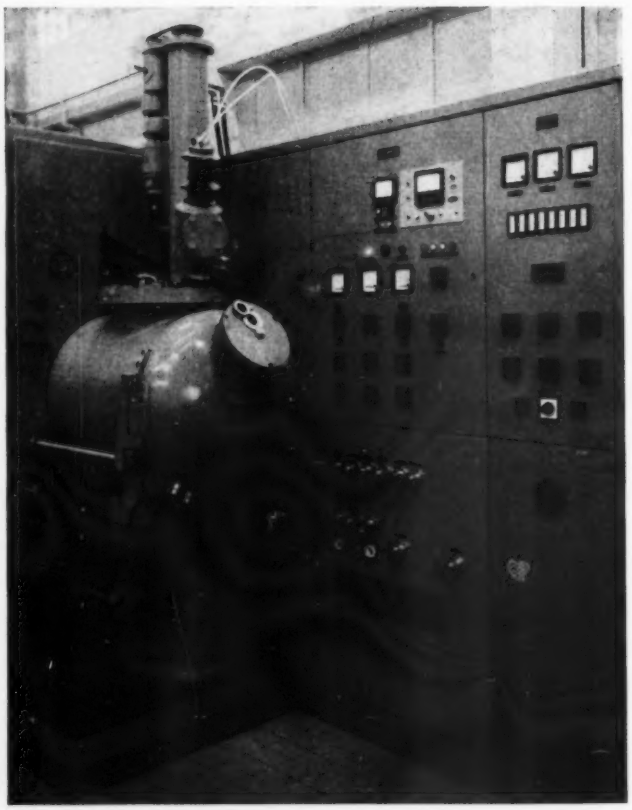

Electron beam melting furnace ES 2/4,
large laboratory type, for melting
and purification purposes.

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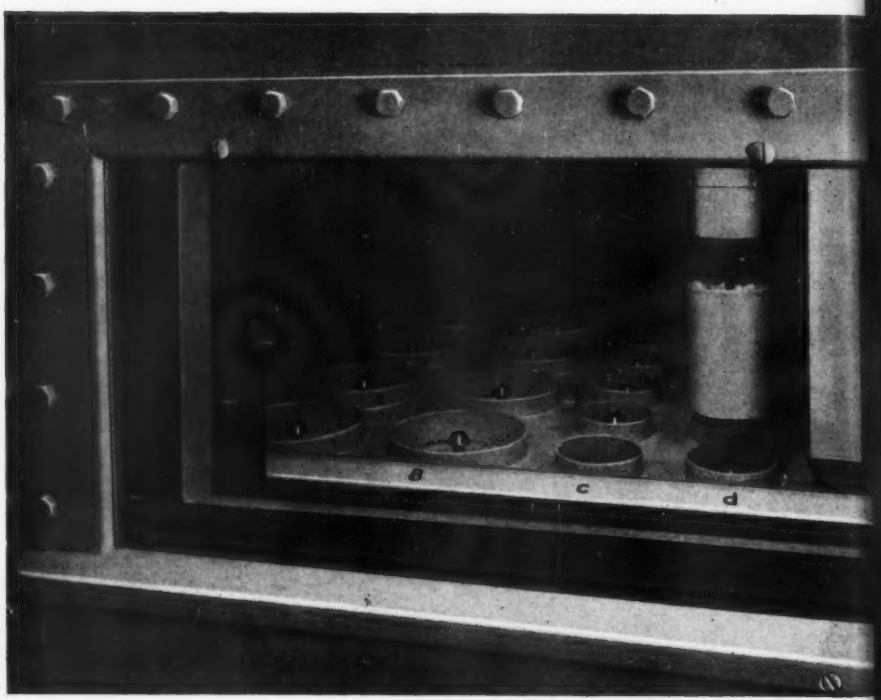

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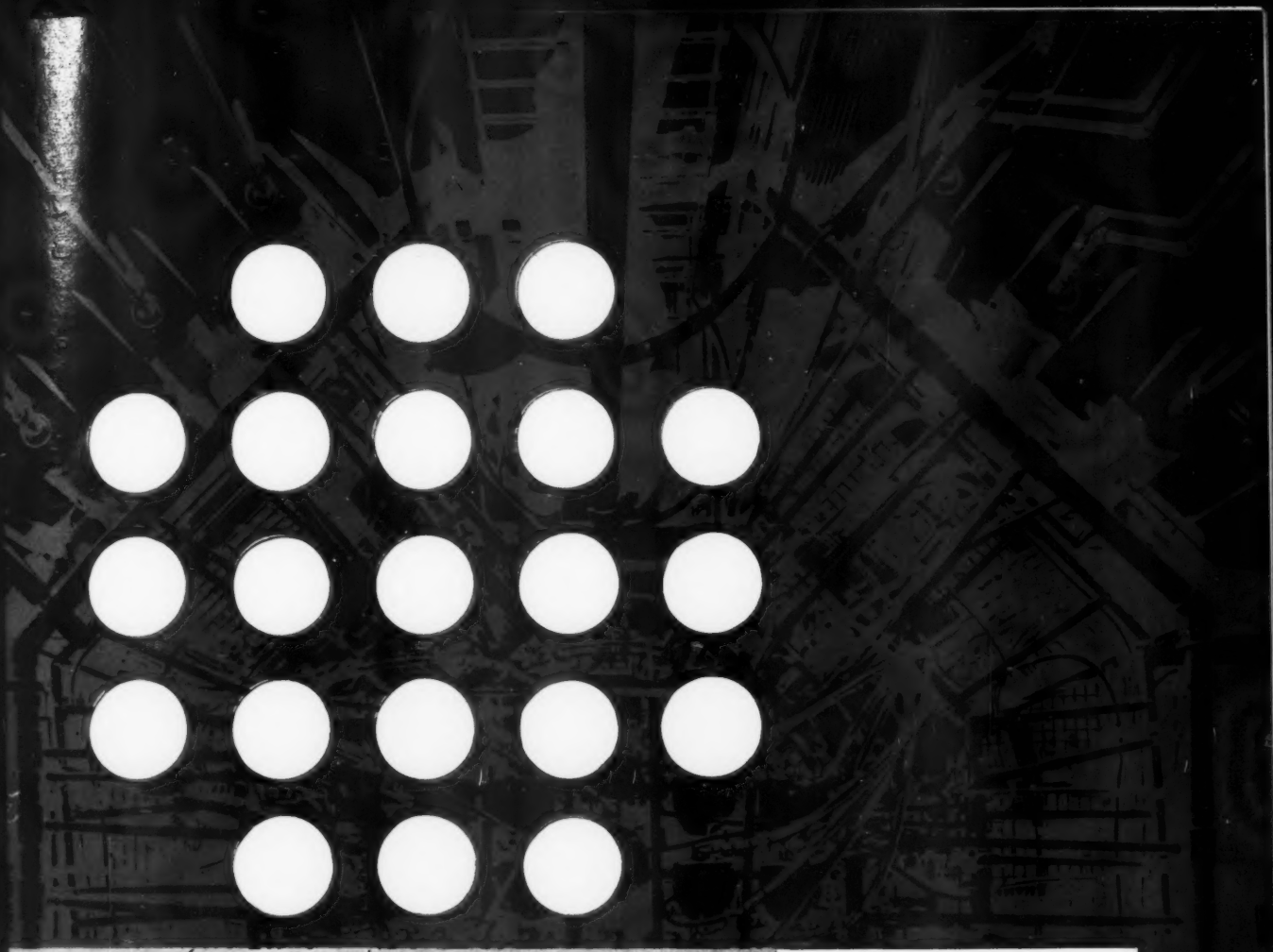

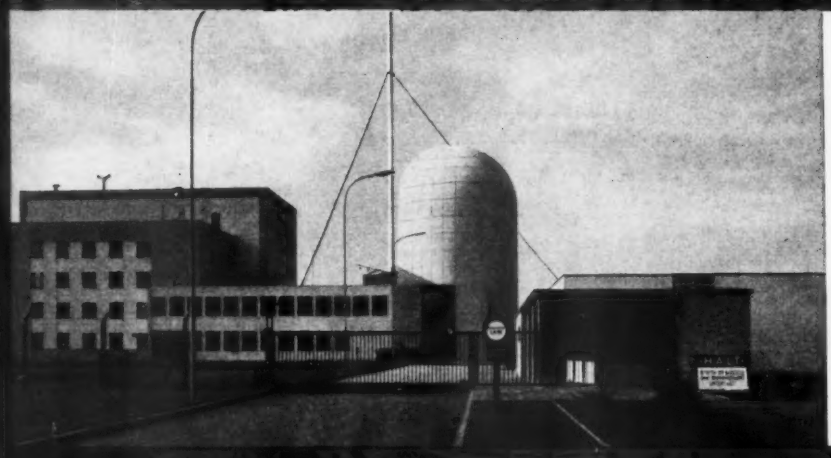

The reactor of the first nuclear power station of the Federal Republic of Germany at Kahl attained first criticality on Nov. 13, 1960 and is now approaching full power operation.

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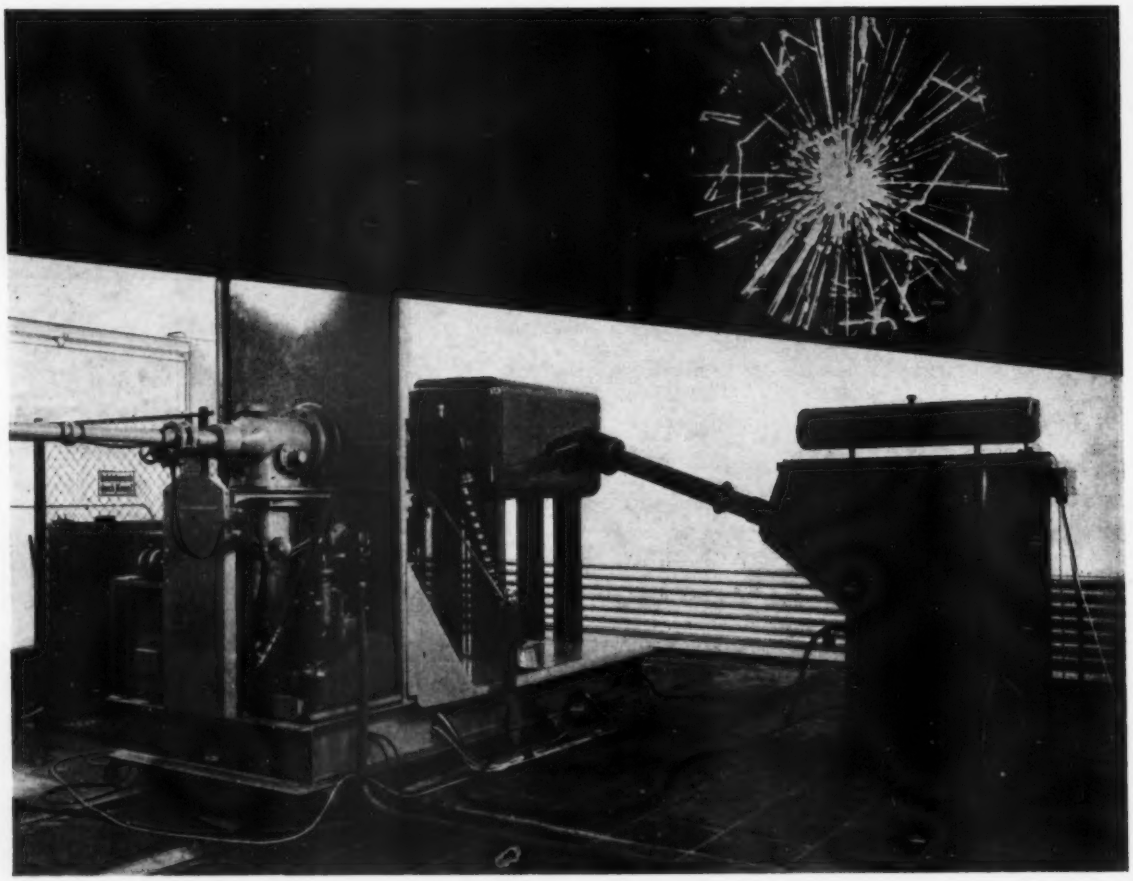

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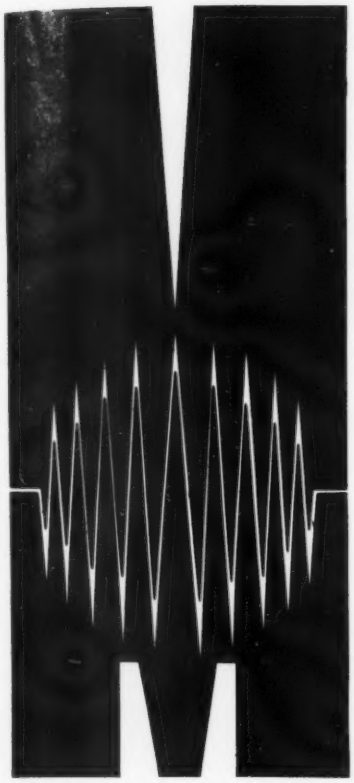

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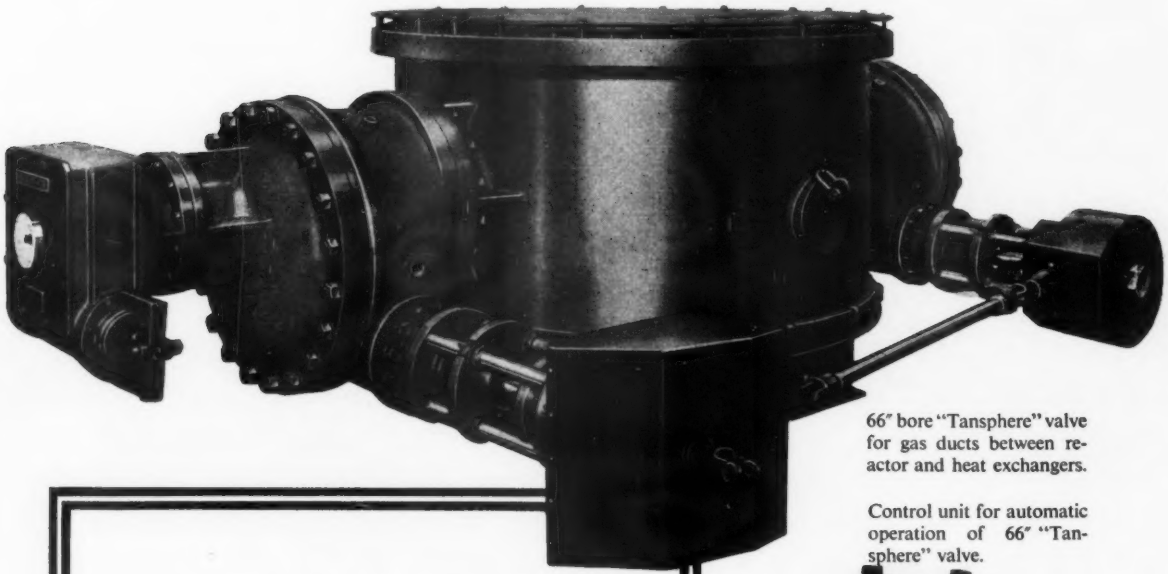
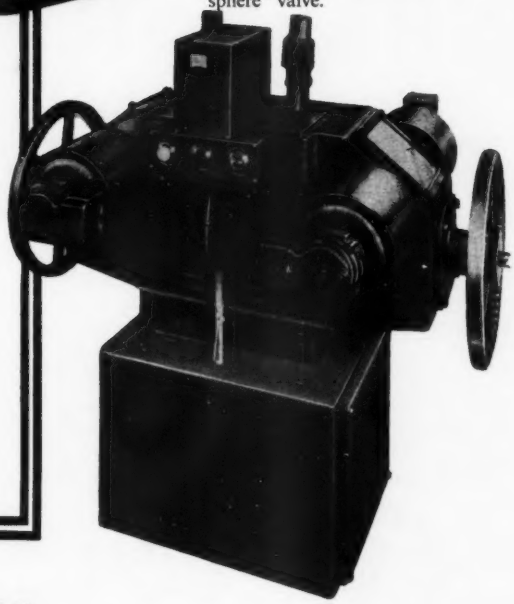


66″ bore "Tansphere" valve for gas ducts between reactor and heat exchangers.

Control unit for automatic operation of 66″ "Tansphere" valve.



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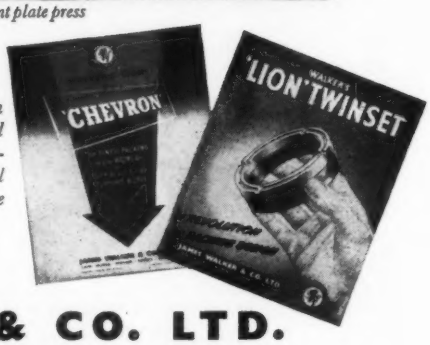

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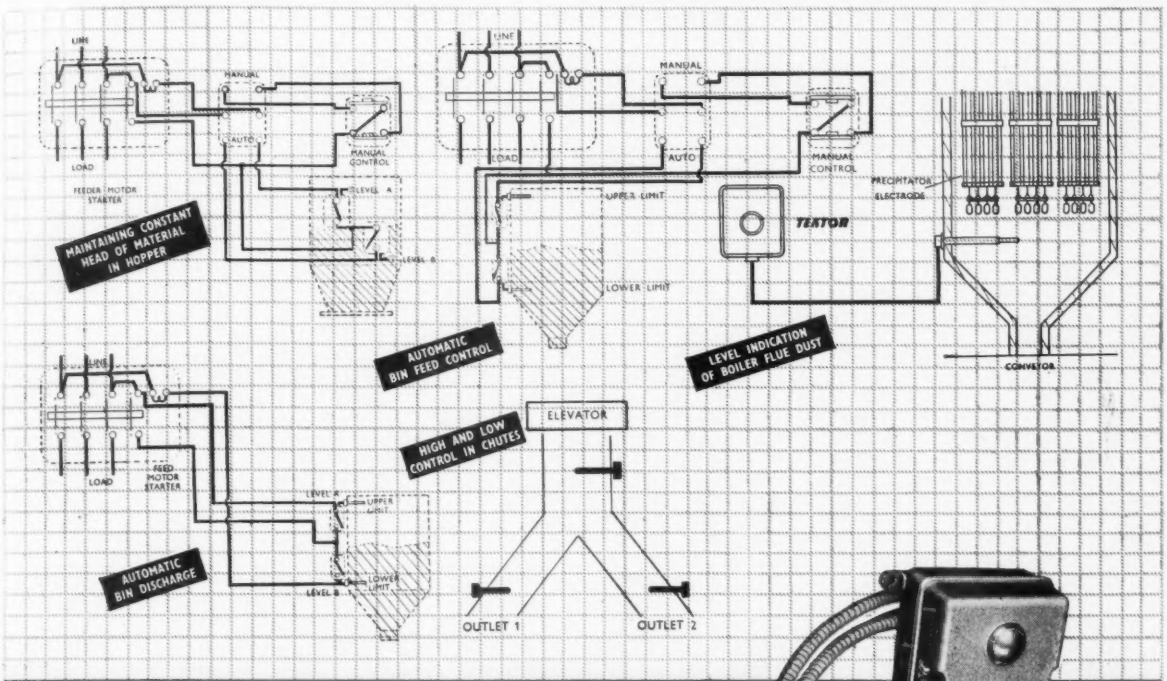

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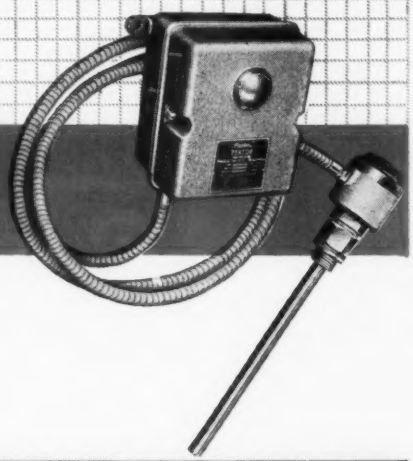

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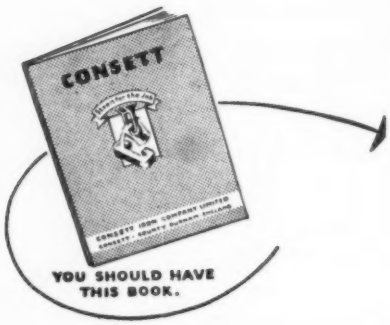

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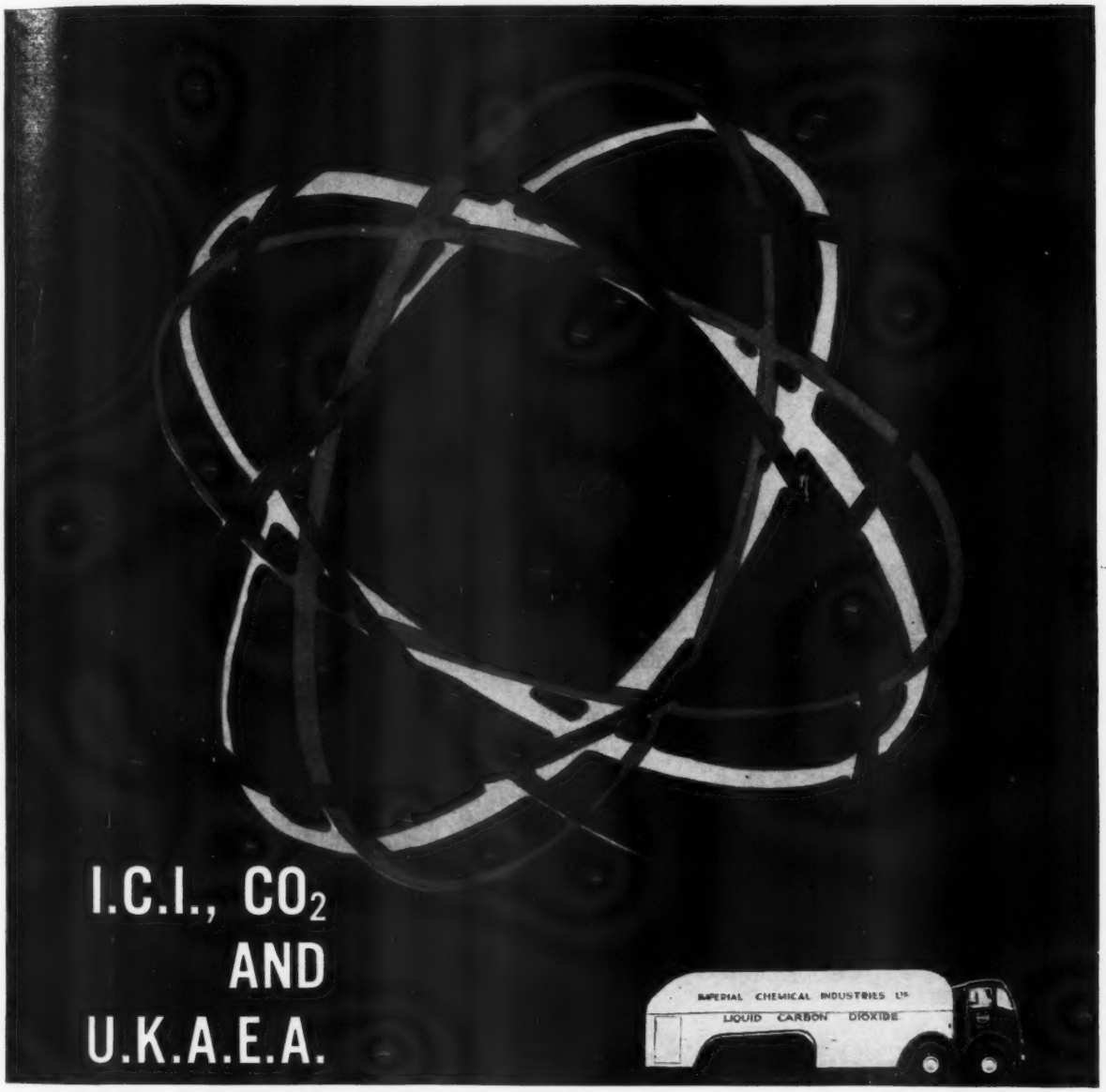

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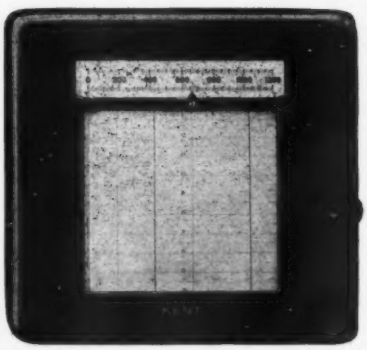

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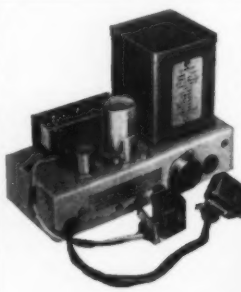

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Nuclear Power
REACTORS MATERIALS INSTRUMENTATION PROCESSES IRRADIATION

MARCH 1961 VOLUME 6 NUMBER 59

VIEWPOINTS letters to the Editor

Jason procedure

SIR: On page 105 of your December issue there is a serious error in the description given of the procedure for measuring the differential control rod worth in JASON.

If any operator should be misguided enough to follow the procedure exactly as described, he will find himself in the embarrassing situation of having both control rods fully withdrawn. Even on a low-reactivity system like JASON this must surely be regarded as undesirable, but on a high flux system the result could well be spectacular.

In view of the increasing numbers of 'private operators' in the reactor operating field, the correct procedure should be published. It should also be made clear that the method is only useful for graphite moderated reactors, and even then is of doubtful value, since the rods are not in their true operational configuration.

K. J. BOBIN
REACTOR SUPERINTENDENT, PLUTO

Direct generation of electricity

SIR: I should like to thank Mr Scorgie (*Viewpoints*, February) for requesting amplification of certain statements in my article; he will understand that, in view of the wide scope, it was necessary to generalize on a number of points so as to give a broad understanding of the characteristics and problems involved.

On the first point, $(T_1-T_0)/T_1$ is merely the Carnot cycle efficiency (see p. 100, Part I, *Nuclear Power*, June 1960) for the thermodynamic process in the generator. It will always be found that the actual efficiency (defined as the ratio of electrical power output to the difference in enthalpy between generator inlet and outlet) will always be less than the temperature function, irrespective of whether the cycle is regenerative.

My statement on the constant-pressure, constant-temperature generator is clearly a simplification of the behaviour in practice, since the electrical conductivity of the gases is not infinite. The electrical conductivity, for a given pressure and alkali metal vapour concentration, is extremely sensitive to temperature; at a given temperature, and for the pressures of interest, the variation with pressure is much less. Consequently, the variation of electrical conductivity in a generator with even approximately constant temperature will be much less than in a constant-velocity generator; this was the main point of the statement, since a wide variation of electrical conductivity implies instability and losses.

The analysis of generator behaviour presents many difficulties; Mr Scorgie and other interested readers may like to refer to recent reports from Westinghouse Electric Corporation[1], [2] and Republic Aviation Corporation[3] in which approximate derivations of theory are given.

DR B. C. LINDLEY
FUTURE STUDIES SECTION
C. A. Parsons & Co. Ltd

1. S. Way, Westinghouse Research Laboratories Scientific Paper 6-40509-2-P2, April 1960.
2. S. Way and R. L. Hundstad, Westinghouse Research Laboratories Scientific Paper 6-40509-2-P3, August 1960.
3. W. Coe and C. Eisen, Republic Aviation Corporation Plasma Propulsion Laboratory PPL-TN-60-7, March 1960.

Isotopes and industry

SIR: Mr Fisher and Mr Johnston in their letters (February, 1961 and September, 1960 respectively) are too severe about industry's 'lack of response' to the use of radioisotopes. Figures showing savings to industry through the use of radioisotopes relate to the year 1958 when questionnaires were circulated to some 700 firms. It was on the basis of their replies that the conservative estimates of £3·5 million annual savings and potential savings of £14·5 million were arrived at. Nearly three years have passed since then and it is reasonable to assume that actual annual savings are now in the region of £5 million or more annually.

One also has to weigh industry's response against the success of industrial applications of radioisotopes. I recall that irradiation of plastic materials to give different properties some years ago, was not as successful or cheap as first thought and was soon replaced by conventional methods which did the job more easily and cheaply.

On balance, one should not express too much dissatisfaction with industry's rate of acceptance of radioisotope techniques. British industry is moving steadily towards further use of radioactive techniques and is hardly as conservative or backward as Mr Johnston would have us believe.

P. BRETTEL
Watford, Herts.

The Israeli reactor

SIR: Gracchus seems to imply that Israel (February issue, p. 82) was under obligation to have made public its intention to build a 24 MW reactor. I do not see that there was any need to do so. Israel, as a sovereign state, was under no such obligation. Rather, I should have thought that Gracchus should have directed his comments towards the undiplomatic methods used by the Americans to obtain further information about the reactor. A public television programme is hardly the usual method of diplomatic intercourse.

*London, E*15 F. DAVIES

Helium price

SIR: With reference to an article appearing in your December issue on page 85, written by Mr P. C. Davidge on the subject of helium, we note that it is stated that the price of helium delivered in Europe in bulk is £30/ft³.

We are interested in knowing whether this figure is correct.

Liquid Metals, Inc. L. G. BULLARD
Westford, Massachusetts

Mr Bullard refers to the sentence '. . . approximate price for helium delivered in Europe in bulk is £30/ft³ . .' This was a printing error and should have read £0·3/ft³ or alternatively £30/1000 cubic feet. Ed.

To keep in closer touch with readers' views and preferences, we have, facing page 51, a readership survey form which readers, in their own interests, are asked to complete and return.

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OPINION

The West German nuclear scene

DISSATISFACTION WITH the rate of progress of Germany's nuclear power programme is being shown in some sectors of German industry. This rate is due partly to the existing system of financial aid, partly to the federal pattern of administration and to having no military nuclear programme to sustain domestic industry (as the Federal Minister points out in his preface to this issue). Some people would like to see overall co-ordination and drive, with some risks taken, stem from a government supported organization similar in structure to the UKAEA or the USAEC. Federal Germany's Atom Commission is only an advisory body with no executive power. A more cogent reason for national restlessness probably comes from comparison with achievements in those countries with a long record of nuclear development — the US, Britain and France.

Even the critics, however, must see that the development of a modern nuclear industry has to progress in an orderly way and takes years to prepare; reliance on a 'crash' programme is not the best philosophy.

Germany's deposits of hard coal and lignite are vast but in view of the continuous increase in power consumption, she will no doubt, in time, be compelled to import some of her fuel. But she is in no great hurry to install nuclear power capacity of any great volume within the next five years at least. The primary aim is rather the provision of experimental plant that will give her the necessary technical and economic experience for the time when competitive large and small plants can be built that relate more realistically to the overall power programme.

Consequently, when she entered the nuclear field in 1955, Germany's first nuclear power programme was not influenced by any compelling need to invest in a number of large uneconomic experimental power plants. One strong influence, however, has been national pride in industrial and technical prowess, and this has pointed to the eventual development of power reactors of German design, with a particular slant towards export models for under-developed countries.

Whilst the 1965 programme is aimed at building five 100MW units, a target that on the face of present progress is going to be hard to attain without importing foreign designs, Germany is working along sound lines by taking, as the first step towards future assessment, the design and development of five different concepts in the small or medium power range. With five years to go for the completion of the existing programme, it is of interest to look at the current situation.

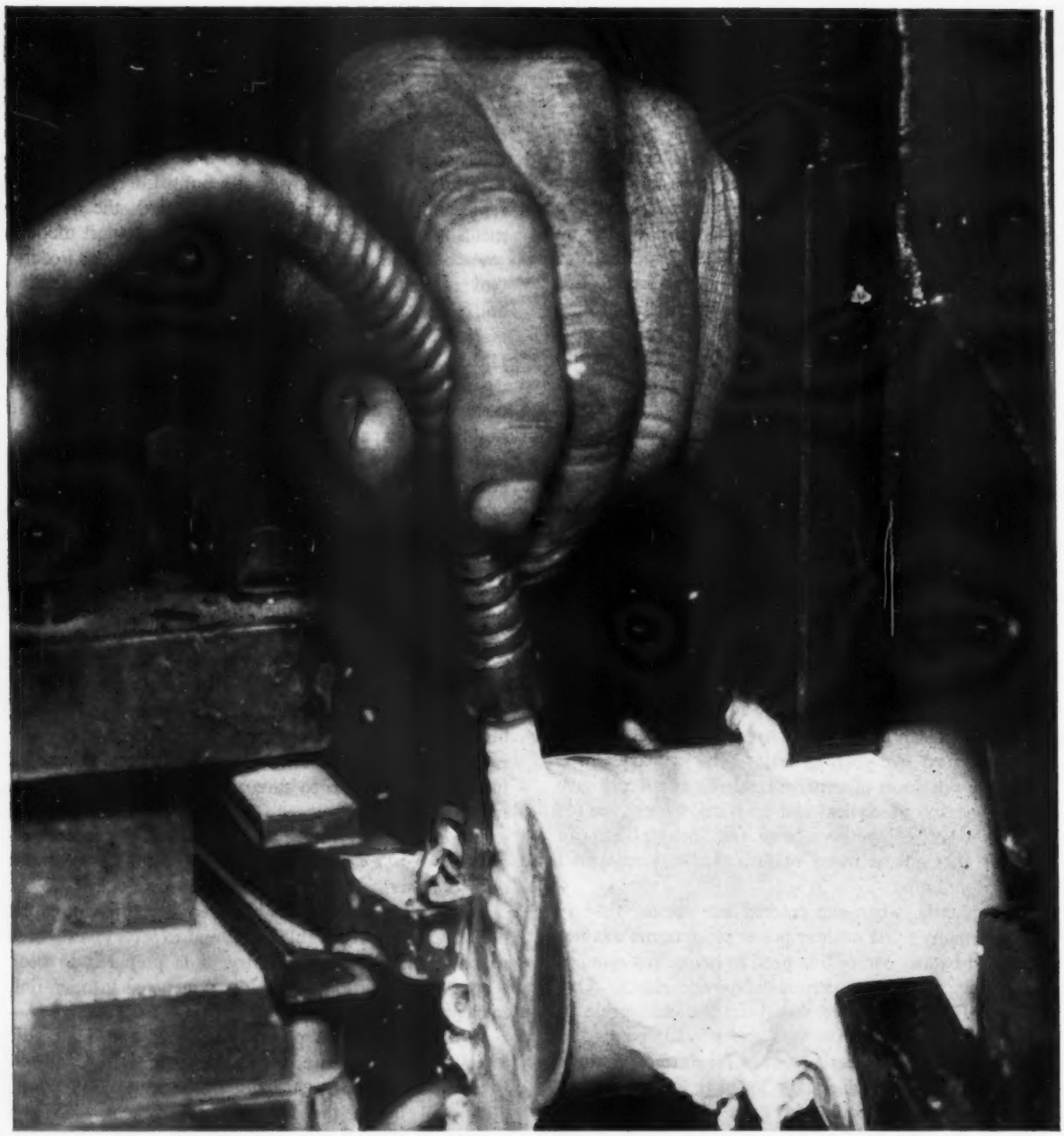
On the credit side, two reactors have gone beyond the paper stage: the 15MWe boiling water reactor of American design that has been critical since November 1960, and the 15MWe gas-cooled pebble bed reactor of German design that is under construction but is not likely to be ready until at least 1963. Although neither is expected to produce power at a competitive price, they represent an important first step towards the development of small reactors that may serve as export models.

Also on the credit side is the support that the Federal Government is giving to universities and other scientific and technological organizations. During the five years of its existence, it has provided a total of some DM.M200 (nearly £M17) towards nuclear research and development; DM.M43 have been allocated for reactor development; the remainder has gone to support the building or expansion of institutes and laboratories, the new nuclear research centres, and for special research equipment in the universities. This, of course, is additional to subsidies from the Land governments. Whether the organization of basic research as we see it in Western Germany is more or less efficient compared with that in other countries, remains to be seen. There is much to be done, but the range of research facilities, both available and to become operational, is impressive.

A large number of plans have been discussed, studied, rejected and amended; on paper are various reactor designs that cover boiling water, advanced gas-cooled, heavy water, high temperature gas-cooled, organic moderated, and pressurized water concepts. Some of these are under two to three year contracts; some will reach the hardware stage. The caution that has been exercised by the utilities, the shipyards and the government is now easing. Whilst the Federal Government does not envisage placing contracts for nuclear power plants, has limited its activities to development work by guaranteeing repayable loans, and expects investments to come mainly from industry, it is prepared to bear a specific proportion of the losses incurred in operating nuclear power plant.

Admittedly KAHL is privately financed and is a credit to industrial enterprise, but of the estimated DM.M40 (over £M3) for the construction of the 15MW AVR plant, 50% will be in the form of government aid. The acceptance of such a share of the total losses is intended as a guarantee for the repayment of interest and capital on the loans that operators of large installations will require to raise on the investment market. These assurances point to a more positive Federal attitude towards the nuclear companies who need definite programmes to keep their scientific and technical staff together, and there is every possibility that the Atomic Ministry, taking note of well-meaning criticisms, will play a more energetic rôle as central co-ordinator in the development of Germany's nuclear power programme.

Shell achievement:



One of Shell's recent achievements in Industrial Lubrication has been to reduce the risk of skin trouble for machine operators. Until the new Shell Dromus range, most modern soluble cutting oils contained phenolic compounds, which can cause skin irritation. They were used as coupling agents between the actual oil and the emulsifier. On high-speed machines, especially, the water evaporates and the emulsion concentrates. And that's when the trouble can start. Shell scientists found a better coupling agent, and made it work. And now, at no extra cost, management can reduce working risks for their staff. *Write for the booklet 'Selecting Your Cutting Oils' to Shell-Mex House, London.*

SHELL

SHELL INDUSTRIAL OILS

WORLDVIEW

the month in atomic energy

EUROPE

New Reactor Group for the AEA

London Major changes announced in the organization of the Atomic Energy Authority will result in the forming of one new group devoted to the design and development of reactors and a rationalization of work between the AEA's remaining groups.

Primary responsibility for scientific and technical co-ordination throughout the Authority will fall upon Sir William Penny. He has been appointed to the new post of Deputy Chairman of the AEA. All the changes will take effect on April 1.

Sir William Cook, at present Member for Development and Engineering, will be the Member for Reactors. Under him will be the *Reactor Group*, formed by modifying the structure of the Development and Engineering Group. This Group will also be responsible for relations in the reactor field with industry at home and with overseas countries. Under its control will come the Winfrith Research Establishment and the Dounreay project.

The changes were decided upon after the Select Committee on Estimates, reporting in 1959 on the Industrial Group, recommended that the system of co-ordination be reviewed. These changes, the AEA say, are designed to improve efficient working.

The Development and Engineering Group's existing responsibilities for design and construction of plant, works and buildings will be transferred to a new *Engineering Group* which will also take over from the *Production Group* its responsibilities for the design and inspection of fuel elements for production purposes.

The structure of the *Research Group*, apart from the transfer of the Winfrith establishment, remains unchanged. The *Weapons Group* is unaffected by the new arrangements.

Sir Leonard Owen's responsibilities will now extend over the Production and Engineering Groups with the title of Member for Production and Engineering.

The AEA also announced that the following appointments will take effect from April 1: director of the Research Group, Dr F. A. Vick (who will continue as director of AERE, Harwell); managing director, Reactor Group, Mr R. V. Moore; managing director, Engineering Group, Mr J. B. W. Cunningham and managing director, Production Group, Mr J. C. C. Stewart.

Jason power record

London Hawker Siddeley Nuclear Power Co.'s privately-owned JASON reactor was recently brought up to and operated at 100 kW—ten times the rating for which this particular version was originally designed. The company also say this is the highest rating that any reactor of this design has so far achieved.

The operation yielded information on the effect of pump failure during operation at 100 kW and the removal of decay heat by thermal convection of air following the reactor scram (with water dumping) from full power. Three runs were made at 100 kW, each of about 20 min duration.

• **United Kingdom** Further limited development on certain problems relating to heavy and light water systems has now been authorized, according to Sir Roger Makins, chairman of the AEA, speaking in India.

French pile completed

Paris A low power pile at Saclay, PEGGY, built for preliminary investigations into the physics of PEGASE, a 30 MWt light water moderated and cooled research reactor, has become operational.

PEGASE is to be built at the Cadarache research centre and will be fuelled by enriched uranium (see 141, *World Reactor Chart*). It will be used for fuel testing.

• **Spain** Formal permission to build a 250 MW nuclear power station on the River Ebro, northern Spain, has been sought by Centrales Nucleares del Norte.

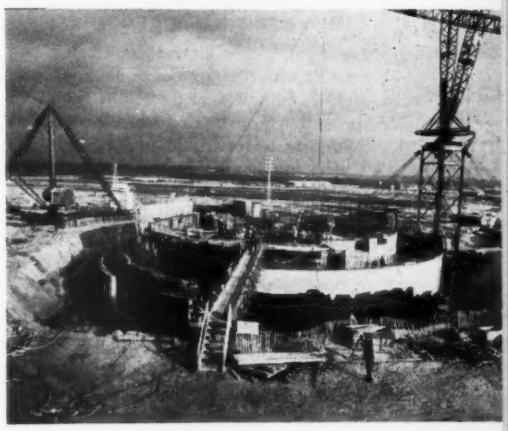
• **Holland** Tenders are being sought for a new building to house an OMR and a critical assembly (KRITO), Reactor Centrum Nederland has announced.

Calder Hall operating experience

London One of Calder Hall's four reactors has completed 12 months continuous operation. During this period, the reactor was generating electricity at full load for 95·6% of the time. Continuous operation was from February 2, 1960 to January 31, 1961 when the reactor was shut down for routine maintenance and change of fuel. No shut-down due to fuel element failure was necessary during these dates.

The period not on full load was accounted for by the following (expressed as a percentage of the total time): experimental work, 2·5; scheduled maintenance of ancillary equipment, 0·7; unscheduled blower maintenance, 0·6; unscheduled maintenance of other equipment, 0·4 and special tests on fuel elements, 0·2.

DRAGON PROJECT. Work is proceeding at a substantial rate on the building for the OEEC Dragon high temperature reactor project. This is a general view of the reactor building during back-filling operations



WORLDVIEW

Parliament looks at nuclear power

London The first experience that Britain will have of small reactors may well be on merchant ships, the House of Commons was told during the recent debate on nuclear power. The announcement was made by Mr J. C. George, Parliamentary Secretary to the Ministry of Power, after some criticism by members of the lack of development plans for small reactors.

The debate itself was opened by Mr John Eden (MP, Bournemouth) who referred to the cost of tendering by the consortia. This was a waste of money, in his opinion. 'It had previously been the practice to assign contracts', he added. 'Could we not make this quite clearly the programme for the remaining three consortia which exist now ?'.

On exports, Mr Eden said he would like the Government to be more positive about encouraging the nuclear industry instead of apparently making it as difficult as possible for exports. He later added: 'I am not the only person who thinks that. The journal entitled *Nuclear Power* in a November, 1960, issue had this to say: "Bumbledom should give way to recognition that the nuclear industry can play a significant part in Britain's export drive". To strengthen our position in overseas markets, the Atomic Energy Authority can do quite a bit under the impetus of the Government in partnership with industry'.

Mr Airey Neave (MP, Abingdon) said the AEA should make full use of the consortia in the design and development of reactor systems. At the moment, the AEA did the basic work, the remainder being handed out piecemeal to the firms in a way that was very unsatisfactory from the planning point of view.

In his reply the Parliamentary Secretary to the Ministry of Power referred to the question of amortization. He pointed out that the life of 20 years for a nuclear power station had been settled on for many sound reasons but 'we are not certain about the life of the stations we are building. We are not certain of the life of the graphite within the reactor but we know with reasonable certainty that techniques will improve'. He added that caution should be exercised.

On the nuclear power programme, Mr George said it was the Government's view that the present programme should sustain an industry of size and efficiency capable of competing with success abroad and of expanding the industry to meet the country's own needs. It was recognized that the cost of tendering had to be borne in the price of a nuclear power station but tendering was a normal, sound business precaution. He did not hold out any hope that competition should be abandoned and selection adopted.

On the economics of small reactors, Mr George said it had been inferred that the AEA was not alive to the importance of small reactors. 'It may be that the first experience that this country will get of small reactors will be on merchant ships,' he continued. 'It has been suggested that we are not devoting a great deal of time to evolving a small nuclear reactor. Our experience from the systems of which we are aware at the moment . . . is that efficiency increases with size. It does not seem possible to construct a small nuclear station to provide power at anything like an economic price.'

Later, Mr George referred to plutonium and said that AEA felt in the long term, this would assist towards the development of small reactors. In the short term, the policy was to learn what was likely to be achieved in marine propulsion and to devote every effort to study what was happening abroad. 'There is a future for small nuclear power stations abroad and indeed at home,' he commented. 'We believe the time has not yet come but, having got a lead in the bigger aspect of power stations, we will not neglect the possibility of getting a lead with the small ones.'

New uranium agreements

London The new agreements entered into by the South African Atomic Energy Board and the USAEC and the UKAEA provide for a stretch-out of uranium deliveries and a fixed price for metal supplied by South African producers. The agreements extend the delivery date from January 1, 1961–1966 of present arrangements to December 31, 1970. The USAEC announced that the new contract will be at a fixed price averaging approximately $11·20 per lb of U_3O_8 FOB vessel, Durban, South Africa, about 60 cents per lb less than the previous price.

• **France** A co-operation agreement on nuclear energy has been signed with South Vietnam.

Hunterston progress

London A start has been made on the installation of the gas circulators and tubing inside two of the five steam raising unit shells associated with the first reactor at Hunterston nuclear generating station, the GEC reports. These five shells have now been placed on their plinths.

Reactor A pressure vessel is being prepared for stress-relief and about a quarter of the bottom head has been externally lagged. The main activity inside Reactor B is connected with the fabrication of the pressure vessel. The scheduled criticality date for Reactor A is August 1962 and for Reactor B, May, 1963.

• **United Kingdom** Work has started at Vickers-Armstrongs' yard at Barrow on prefabricated sections for Britain's second nuclear submarine.

• **United Kingdom** The Electricity (Amendment) Bill enabling the CEGB to produce radioisotopes has been passed by the House of Commons. It was given a second reading in the House of Lords recently.

• **Holland** The NV Neratoom combine is to build a core-support structure for the OEEC DRAGON high-temperature reactor project.

• **Belgium** About 2900 million francs has been invested in the Mol centre, the Under Secretary of State for Power Economy told the Senate.

• **France** The US has supplied 20 kilograms of enriched uranium for the prototype submarine project being built at Cadarache.

Concrete pressure vessel for EDF-3

Paris The proposed 400 MW EDF-3 power reactor is to have a concrete pressure vessel, Electricité de France announced recently. After long study, the company stated, this material was preferred to the steel vessels used in EDF-1 and EDF-2.

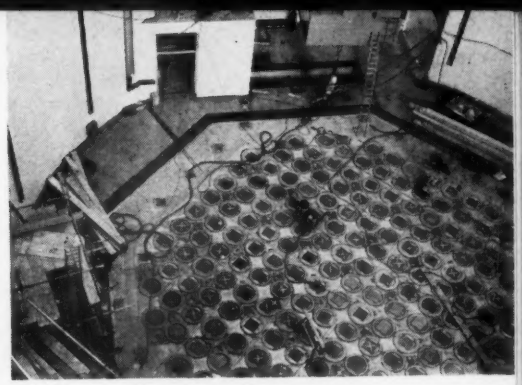
This expected announcement came after it was disclosed at the Atomic Industrial Forum annual conference that for conditions in France, it was cheaper to use steel vessels for reactors in the range of 200 MW and pre-stressed concrete above 200 MW. This was stated by M. Andre Hannothiaux, Contrôleur Général de l'Equipment, Electricité de France, in a paper before the conference.

Referring to EDF-3, M. Hannothiaux said it would be the last reactor built at the Chinon site. It would have a net electrical output capacity of at least 400 MW (with two generating units of 250 MW each). He added: 'The originality of this gas-cooled reactor resides in the fact that the vertical reactor vessel will be made out of pre-stressed concrete. We have adopted this technique strictly for economic reasons. For EDF-3, we have put the conventional steel vessels in competition with pre-stressed concrete vessels. The bids we have received show that, for the conditions existing in France, it is cheaper to use steel vessels for reactors in the range of 200 MW net and pre-stressed concrete above 200 MW'.

For EDF-4, nothing definite had been decided. The tendency at this time would be to use a design similar to that of EDF-3. M. Hannothiaux pointed out: 'We feel that the size we are planning for EDF-3 i.e. 500 MW gross for the second core, is probably the optimum size for a reactor producing power at a competitive cost. And EDF-4 may well be the first in a series of reactors which could compete economically with conventional stations'.

Hinkley pressure vessel is tested successfully

London The No. 1 reactor pressure vessel at the 500 MW Hinkley Point nuclear power station has been successfully pressure-tested at the highest pressure so far produced in vessels of this kind, says an English Electric/Babcock & Wilcox/Taylor Woodrow announcement. The operation was carried out without incident and completed six hours ahead of schedule. The pressure vessel, a 67 ft diameter sphere with 3 in thick mild steel plate, withstood a pressure of 310 lb/in², over 1½ times the pressure it will have to stand in service.



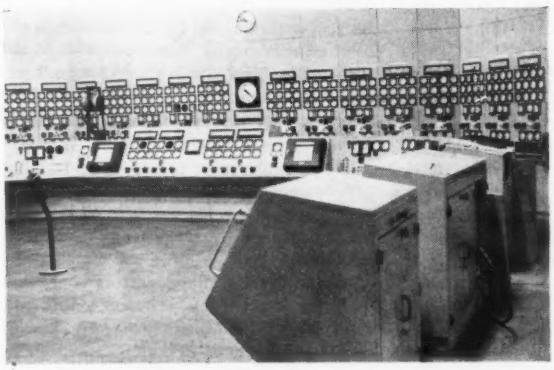
BERKELEY POWER STATION

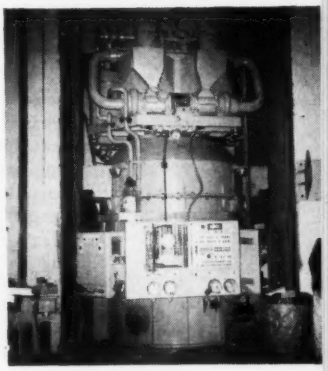
One reactor at Berkeley is due to come into operation before the end of this year. No. 1 reactor will be charged with fuel in April and the charge/discharge machinery was recently scheduled to undergo testing with actual fuel elements

New plasma project at Aldermaston

Glasgow Research work on project Phoenix at the Atomics Weapons Research Establishment, Aldermaston, was described by Dr S. C. Curran, principal of the Royal College of Science and Technology, in his Kelvin lecture to the Royal Philosophical Society of Glasgow recently.

This plasma experiment, using the mirror principle, was designed to raise a small mass of hydrogen to a temperature of more than 100 million degrees Centigrade, forming a tiny star which would last for about a second and could be repeated as often as desired.





Top right: The pile cap of No. 2 Reactor immediately after the final concrete pour of the cap and prior to the establishment of 'clean conditions'. Top left: The turbine hall showing the four 83 MW turbo alternators virtually complete. Bottom right: One of the charge/discharge machines immediately prior to test on the pile cap of No. 1 Reactor. Bottom left: A section of the main Control Room showing all the boiler controls in the background and the control dais

New AEA reactor

London A Versatile Experimental Reactor Assembly, VERA, went critical on February 22 at Aldermaston. This low power reactor has a variable core composition and will be used to study the safety and storing of fissile material. It is designed to separate into two parts for safe loading. The two parts are brought together slowly by remote control.

Consortia team may visit the Soviet Union

London A British team drawn from the consortia may visit the Soviet Union. *Nuclear Power* understands that preliminary approaches from Soviet officials have been made with a view to an exchange of Soviet and British teams in the reactor design and construction field. Basis for the exchange is the recent Soviet-British cultural agreement which provides for an exchange of scientific personnel.

• **Sweden** The Stockholm Isotope-Technical Laboratory reports that main work in the first year of operation has concentrated on tracer methods.

Cockcroft on fuel burn-up

London British experience in the 'burn-up' of fuel elements has so far reached a maximum of 2000 megawatt days per ton, Sir John Cockcroft told a symposium at Trombay, India, recently.

He added that of approximately 10,000 fuel elements that were loaded into each reactor at Calder Hall every year, only about 0·05% developed faults during the one year irradiation period. These faults had been due either to a small hole in the end weld which went undetected by the inspection proceeded in the factory or to faults in welds produced by subsequent handling or to intergranular leakage.

As a result of accumulated experience, confidence was now felt that the design target of an average irradiation of 3000 megawatt days per ton for CEGB power stations would be reached.

The reaction between carbon dioxide and graphite leading to carbon monoxide formation which could lead to mass transfer of carbon if it were excessive had been studied. Sir John added: 'Our experience shows that the carbon monoxide concentration increases to 0·5% and confirms predictions made from experiments we carried out on this reaction in our research reactor BEPO. We have not been able to detect any mass transfer of carbon.'

Sir John later pointed out that the temperature of operation in the first generation of CEGB stations was limited by the increasing plasticity of uranium metal and of the magnesium alloy cans. These limitations could be removed by changing to uranium oxide fuel elements canned either in stainless steel or possibly beryllium metal. Sintered UO_2 had a melting point of about 2300°C and it withstood radiation damage very well so that burn-ups of the order of 10,000 megawatt days per ton should ultimately be possible.

Because of the high operating temperature (of the AGR), the reaction between CO_2 and graphite leading to CO production and possible mass transfer of carbon would be more important and experiments had been carried out in BEPO and DIDO to check whether this gas reaction would lead to difficulties. Present results suggested that by maintaining the CO concentration at a level of about 5%, the gas reaction should not be troublesome.

WORLDVIEW

OVERSEAS

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Meanwhile, shipments of radioisotopes to foreign countries continued to increase. The AEC and private processors, combined, made some 4857 shipments during 1960 compared with 3252 in 1959.

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The continued rise in the number of industrial licenses occurred after major manufacturers of gauging equipment began operating after an AEC regulation which permits the sales of gauges under general licenses instead of under an individual license for each user. It is now estimated that between 5000 to 6000 radioisotope gauges are now in use of which some 1000 were marketed during 1960. Radioisotopes and equipment imported into the US during 1959 totalled more than $1·1 million of which more than 80% came from Canada.

Fuel processing: Orders placed by the AEC and its principal contractors with commercial sources for conversion of uranium hexaflouride to materials suitable for fuel elements, and for the fabrication of fuel elements rose from $41·4 million (£15 million) in 1959 to $52·4 million (£18·5 million) in 1960, an increase of 26%. The amounts represented, in large part, orders for naval reactor cores.

Other items from the report include:

A decision not to proceed with the helium cooled, graphite moderated 3 MWt TURRET reactor planned by Los Alamos Scientific Laboratory because of greatly increased costs and because other reactors could be used for experiments. TURRET was to demonstrate very high temperature gas-cooling with unclad uranium impregnated graphite fuel.

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Expenditure for that year is estimated at $2·68 thousand million dollars compared with $2·66 thousand million in 1961. During the year, two more high energy accelerators, at Cambridge, Mass., and Princeton, New Jersey, will begin operation. The total number of major Government-owned experimental power reactors in operation will increase by five to a total of 10 and the number of power reactors operating in public and private utility systems will increase from three to 10. The 1962 budget proposes additional funds for co-operative arrangements with private and public power groups in undertaking atomic power projects which would further the objectives of the development programme.

• **India** Tenders for the 300 MW Tarapore plant have to be submitted by the end of March, according to Dr H. J. Bhabha chairman of the Indian AEC. The Commission intends to produce the fuel for the project.

• **Japan** A team of five experts is to visit the USA, the UK, France and Belgium on a 50 day tour in early April to study reprocessing of nuclear fuel.

• **United States** AMF Atomics has asked for a ten month extension of its licence to export the rest of a 1 MW research reactor to the Portuguese Junta de Energia Nucleari because of delays to the latter's construction programme.

• **USSR** The Soviet Union has offered to help Pakistan develop her nuclear power programme.

Los Angeles withdraws from BWR project

Los Angeles The Los Angeles Department of Water and Power has now informed the AEC that it wants to withdraw from the project to build a 50 MW Intermediate Cycle BWR at Haskell Canyon. This decision follows the recent announcement by the AEC that Allis-Chalmers had been selected to build the plant after previously stating that GE of the US had been awarded the contract (See *Worldview*, February, p 58).

Reasons for the Los Angeles Withdrawal are that the AEC Reactor Safeguards Committee thinks the chosen site is unsuitable for a larger reactor than the one planned (the 50 MW BWR was a prototype for a 300 MW plant) and because the project will now cost more than originally planned. The city of Pasadena was associated with the project.

Japan seeks second reactor

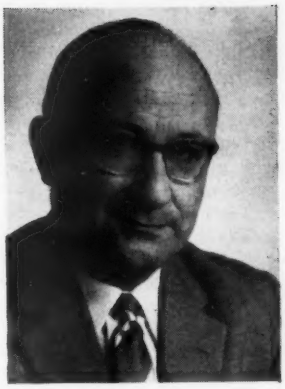
Tokyo A final decision on a second power reactor for Japan is likely soon. This follows a recent meeting by heads of nine electric utilities when it was proposed that the Japan Atomic Power Company, the company building the Tokai-Mura 150 MW reactor, be responsible for installing the reactor, probably in the Kansai district.

It was also stated recently in the British House of Commons by the Parliamentary Secretary to the Ministry of Power that Japan was considering a second (nuclear power) station. He was speaking in a debate on the British nuclear power programme (see *Worldview* this issue).

Under the revised Development Programme for Nuclear Power, the Japanese AEC foresees that in the first 1000 MW stage (up to 1970) five reactors would be built and imported. The AEC has urged that an early decision be made on a light water reactor type for the second import.

ATOMIC ENERGY IN THE GERMAN FEDERAL REPUBLIC

Atomic Energy in the German Federal Republic



Dr Siegfried Balke, Federal Minister for Atomic Energy, writes this preface for Nuclear Power's *special issue on German developments*

THE CURRENT position and development trends in the German atomic industry are, for the most part, conditioned by two main factors. The first is that on political grounds, the Federal Republic could not begin nuclear research and development work until May, 1955, by which time reactor types were on hand in the leading nuclear countries.

This belated entry means that an industrialized country has to make up this leeway over a period of years. But there is also an advantage to this late start. German industry can learn from the experience of overseas associates, i.e. it can buy tried and tested equipment on the open market and it does not need to carry out again work which has been completed. In view of this, German development work, particularly on reactors, is based on adopted designs or the further development of concepts from abroad. Domestic building, such as high temperature reactors, only started recently.

The second point is that because the Federal Government has renounced the manufacture of nuclear weapons, military considerations do not enter into the planning of German nuclear programmes. Development now in progress is aimed solely at peaceful purposes. This renunciation means that Germany's nuclear industry, in contrast with that in countries producing nuclear weapons, will not benefit from funds accruing from military budgets.

The energy policy pursued by the Federal Government aims at incorporating the nuclear energy industry into the normal competitive framework. Then, the public utilities can decide on the basis of competitive considerations whether, and when, they wish to cover the increase in energy requirements in their supply area with heat and electrical energy from fission. In this way, the rate of investment in large nuclear power stations depends primarily on their competitiveness with conventional stations.

Since the principle of free competition demands basically that energy production installation investment be covered by private initiative, it is understandable that electricity producers strive mainly to cover the financial risks that they, without doubt, will incur by building nuclear power stations—as long as the cost of nuclear units is higher than that of power from other sources. Even though the margin of risk is influenced both by changes on the energy market—which can be very rapid—and by the locality, the question of investment financing of nuclear power stations is, nevertheless, well to the fore in the Federal Republic

With my encouragement, the German reactor industry has prepared a supplementary programme for the development and construction of prototypes of medium-powered reactors. These are of special interest for underdeveloped countries who are just building up their own industries. I believe it expedient to point out here that the German reactor firms which began four or five years ago to develop reactors of around 125 MW, have maintained their choice of reactor type for the supplementary programme for medium sized units. Certainly, this is in part due to the fact that some companies can obtain details of progress abroad with specified reactors. However, it also demonstrates that all the types believed four or five years ago by German industry to be promising, are still considered so.

Activity to date shows that the German development programmes are not as ambitious as in countries with advanced nuclear technology. Nevertheless, it does ensure that in the framework of world development, Germany will have a substantial place. The major concern in West Germany is to support scientific research and to maintain technological development which will guarantee the availability of up-to-date techniques when economic conditions are ripe.

As the Federal Minister responsible for the development of nuclear technology, I am striving to steer a course between the Scylla of atomic hysteria and the Charybdis of atomic apathy. This demands a sober appraisal of all the possibilities inherent in this new development. A highly industrialised country such as ours must not do so little that she cannot meet international commitments in a way commensurate with her international economic importance. Germany must also not do too much so as not to be suspected of working on projects which she has renounced.

I am sure that this philosophy is valid both politically and economically. It rejects sensational and utopian plans; it is continuously striving to develop scientific bases and stems from the certainly that the dangers of this new technology can be overcome by enlightened work. The industrial application of nuclear energy will assure and expand the possibilities of human existence.

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More funds for AEC reactor projects

Washington Major development work on seven reactor types and preliminary studies and experimental work on a number of other reactor concepts will cost an estimated $250 million (£90 million) in 1962 according to the Atomic Energy Commission's budget for the year ending June 30, 1962.

Expenditure for that year is estimated at $2·68 thousand million dollars compared with $2·66 thousand million in 1961. During the year, two more high energy accelerators, at Cambridge, Mass., and Princeton, New Jersey, will begin operation. The total number of major Government-owned experimental power reactors in operation will increase by five to a total of 10 and the number of power reactors operating in public and private utility systems will increase from three to 10. The 1962 budget proposes additional funds for co-operative arrangements with private and public power groups in undertaking atomic power projects which would further the objectives of the development programme.

• **India** Tenders for the 300 MW Tarapor plant have to be submitted by the end o March, according to Dr H. J. Bhabha chairman of the Indian AEC. The Com mission intends to produce the fuel for the project.

• **Japan** A team of five experts is to visit the USA, the UK, France and Belgium on a 50 day tour in early April to study reprocessing of nuclear fuel.

• **United States** AMF Atomics has asked for a ten month extension of its licence to export the rest of a 1 MW research reactor to the Portuguese Junta de Energia Nuclear because of delays to the latter's construction programme.

• **USSR** The Soviet Union has offered to help Pakistan develop her nuclear power programme.

Los Angeles withdraws from BWR project

Los Angeles The Los Angeles Department of Water and Power has now informed the AEC that it wants to withdraw from the project to build a 50 MW Intermediate Cycle BWR at Haskell Canyon. This decision follows the recent announcement by the AEC that Allis-Chalmers had been selected to build the plant after previously stating that GE of the US had been awarded the contract (See *Worldview*, February, p 58).

Reasons for the Los Angeles Withdrawal are that the AEC Reactor Safeguards Committee thinks the chosen site is unsuitable for a larger reactor than the one planned (the 50 MW BWR was a prototype for a 300 MW plant) and because the project will now cost more than originally planned. The city of Pasadena was associated with the project.

Japan seeks second reactor

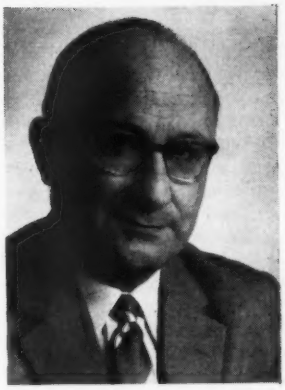
Tokyo A final decision on a second power reactor for Japan is likely soon. This follows a recent meeting by heads of nine electric utilities when it was proposed that the Japan Atomic Power Company, the company building the Tokai-Mura 150 MW reactor, be responsible for installing the reactor, probably in the Kansai district.

It was also stated recently in the British House of Commons by the Parliamentary Secretary to the Ministry of Power that Japan was considering a second (nuclear power) station. He was speaking in a debate on the British nuclear power programme (see *Worldview* this issue).

Under the revised Development Programme for Nuclear Power, the Japanese AEC foresees that in the first 1000 MW stage (up to 1970) five reactors would be built and imported. The AEC has urged that an early decision be made on a light water reactor type for the second import.

ATOMIC ENERGY IN THE GERMAN FEDERAL REPUBLIC

Atomic Energy in the German Federal Republic



Dr Siegfried Balke, Federal Minister for Atomic Energy, writes this preface for Nuclear Power's *special issue on German developments*

THE CURRENT position and development trends in the German atomic industry are, for the most part, conditioned by two main factors. The first is that on political grounds, the Federal Republic could not begin nuclear research and development work until May, 1955, by which time reactor types were on hand in the leading nuclear countries.

This belated entry means that an industrialized country has to make up this leeway over a period of years. But there is also an advantage to this late start. German industry can learn from the experience of overseas associates, i.e. it can buy tried and tested equipment on the open market and it does not need to carry out again work which has been completed. In view of this, German development work, particularly on reactors, is based on adopted designs or the further development of concepts from abroad. Domestic building, such as high temperature reactors, only started recently.

The second point is that because the Federal Government has renounced the manufacture of nuclear weapons, military considerations do not enter into the planning of German nuclear programmes. Development now in progress is aimed solely at peaceful purposes. This renunciation means that Germany's nuclear industry, in contrast with that in countries producing nuclear weapons, will not benefit from funds accruing from military budgets.

The energy policy pursued by the Federal Government aims at incorporating the nuclear energy industry into the normal competitive framework. Then, the public utilities can decide on the basis of competitive considerations whether, and when, they wish to cover the increase in energy requirements in their supply area with heat and electrical energy from fission. In this way, the rate of investment in large nuclear power stations depends primarily on their competitiveness with conventional stations.

Since the principle of free competition demands basically that energy production installation investment be covered by private initiative, it is understandable that electricity producers strive mainly to cover the financial risks that they, without doubt, will incur by building nuclear power stations—as long as the cost of nuclear units is higher than that of power from other sources. Even though the margin of risk is influenced both by changes on the energy market—which can be very rapid—and by the locality, the question of investment financing of nuclear power stations is, nevertheless, well to the fore in the Federal Republic

With my encouragement, the German reactor industry has prepared a supplementary programme for the development and construction of prototypes of medium-powered reactors. These are of special interest for underdeveloped countries who are just building up their own industries. I believe it expedient to point out here that the German reactor firms which began four or five years ago to develop reactors of around 125 MW, have maintained their choice of reactor type for the supplementary programme for medium sized units. Certainly, this is in part due to the fact that some companies can obtain details of progress abroad with specified reactors. However, it also demonstrates that all the types believed four or five years ago by German industry to be promising, are still considered so.

Activity to date shows that the German development programmes are not as ambitious as in countries with advanced nuclear technology. Nevertheless, it does ensure that in the framework of world development, Germany will have a substantial place. The major concern in West Germany is to support scientific research and to maintain technological development which will guarantee the availability of up-to-date techniques when economic conditions are ripe.

As the Federal Minister responsible for the development of nuclear technology, I am striving to steer a course between the Scylla of atomic hysteria and the Charybdis of atomic apathy. This demands a sober appraisal of all the possibilities inherent in this new development. A highly industrialised country such as ours must not do so little that she cannot meet international commitments in a way commensurate with her international economic importance. Germany must also not do too much so as not to be suspected of working on projects which she has renounced.

I am sure that this philosophy is valid both politically and economically. It rejects sensational and utopian plans; it is continuously striving to develop scientific bases and stems from the certainly that the dangers of this new technology can be overcome by enlightened work. The industrial application of nuclear energy will assure and expand the possibilities of human existence.

ATOMIC ENERGY
IN THE GERMAN
FEDERAL REPUBLIC

Large scale introduction of nuclear power in West Germany is unlikely in this decade; even in the 1970's it will not alter the country's energy situation substantially

WEST GERMANY'S ENERGY POSITION

by Dr WOLFGANG FINKE,
Federal Ministry of Nuclear Energy and Water Economy

PRIMARY ENERGY consumption in West Germany* during the past decade rose from 126 million to 184 million tons in terms of coal equivalent. During the same period, domestic primary energy production rose from 142 million to 169 million tons of coal equivalent. From a net exporter of primary energy, the Federal Republic since 1955 has become a net importer. It is unlikely that this trend will be reversed in the foreseeable future; instead, it is anticipated that during the next decade, primary energy consumption will increase more rapidly than domestic primary energy production.

The disproportionate increase in energy requirements compared with output is, however, only one aspect of the rapidly changing energy situation in West Germany. A second closely linked aspect, is the simultaneous massive change in the structure of energy requirements in the country: the steady increase in the share of liquid fuels of the total energy consumption, on the one hand, and the continued switch in demand from primary to secondary energy forms, on the other.

Changing pattern of demand

In 1929, some 97·5% of West Germany's crude energy consumption was covered by solid fuel—77·3% coal and 20·2% brown coal, pitch coal and peat. Thirty years later, the share of solid fuels dropped to 77·6%—60·1% coal, 17·5% brown coal, pitch coal and peat. In the same period, the share of mineral oil in crude energy consumption increased from 1·3% to 19·9% and meanwhile has risen still further.

Parallel with these developments, demand for secondary energy grew. In 1937, half of West Germany's final energy requirements were still being met by primary energy sources in their original form—mainly by coal—and by 1959, this total had fallen to 28%. This development, too, has continued in recent months and can be expected to proceed still further.

The change in the pattern of demand has both technological and commercial causes. But no justification can be found for it in the composition of domestic energy supplies. West Germany, including the Saar, is primarily a coal-based area. Known reserves of hard coal up to a depth of 1200 metres are put at some 70,000 million metric tons. At the present extraction rate, these would last for about 500 years. Deposits of at least the same volume are presumed to exist at depths from 1200–2000 metres. Smaller, but still very important, are the exploitable brown coal reserves. These are estimated at 62,000 million tons and would be sufficient to sustain current production levels for over 650 years.

With other energy sources, the picture is quite different. The known and probable petroleum reserves in the country are now put at not more than 73 million tons. These would be exhausted in 14 years if the output figure of 5·1 million tons reached in 1959 were to be maintained. It is also probable that no large natural gas reserves exist in West German territory. This also applies to uranium ore deposits. Exploitable uranium reserves are estimated at a few hundred tons at the most and thorium deposits have so far not been found. Demand for these energy sources in the foreseeable future will have to be met exclusively by imports.

Finally, the Federal Republic has a hydro-electric potential of 23 million MWh annually. At present, just over half is actually used. The installed capacity of the hydroelectric plants is about 57% of possible capacity and annual output represents about 3% of total West German primary energy production.

Production of primary energy

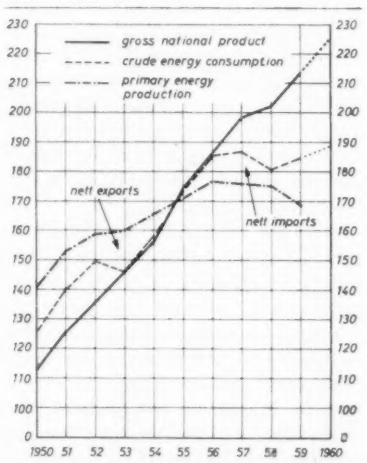
The composition of the country's energy reserves is reflected in its primary energy production. Here again, coal completely dominates the picture even though its share has steadily declined in the past ten years. In 1959, coal produced accounted for 155 million tons in terms of coal equivalent. This was nearly 92% of total domestic primary energy production. It was composed of 126 million tons of hard coal; the remainder was mostly brown coal with a little pitch coal. Peat and wood accounted for a further two million tons in hard coal units.

In contrast, petroleum produced in the Federation during 1959 was the equivalent of 7·3 million tons of hard coal. In the same year, natural gas output was around 0·5 million tons in hard coal units. Power from hydro plants represented the equivalent of 4·1 million tons.**

The largest export item in the West German energy balance sheet is, understandably, hard coal. During the past ten years, exports have ranged from 23 to 26 million tons, the overall tendency being slightly downwards. Of

*Unless otherwise indicated statistics do not cover the Saar. If this area is included, primary energy consumption in 1959 was 198 million tons hard coal equivalent and production about 185 million tons.

**One kWh is taken as the equivalent of 0·4 hard coal units.



Germany's gross national product, primary energy production and crude energy consumption 1950-60

this, some threequarters went to the European Coal and Steel Community countries. On the other hand, in the same period, considerable amounts of hard coal were imported. Imports in 1957 reached an all-time peak of 23 million tons, of which 16 million tons came from the USA. When the coal sales crisis began early in 1958, imports fell off sharply. In 1959, they were only 11·7 million tons and since then have continued to drop.

Considerably different is the picture of the development of petroleum imports and exports. Crude oil imports alone increased in the last decade from 2·3 to 16·8 million tons while imports of petroleum products rose from barely two million tons in 1955 to about five million in 1959. In the same year, however, some 2·3 million tons of products were re-exported.

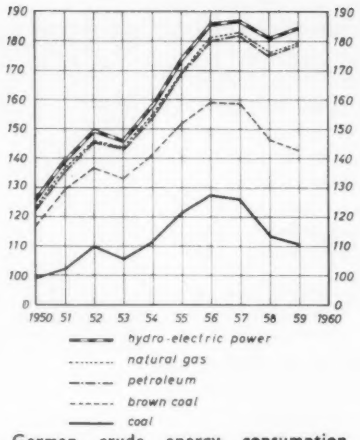
Electricity

The preponderance of coal in the supply of primary energy in West Germany also determines the structure of the electricity supply industry. Gross electricity output was 103 million MWh in 1959 of which 63 million MWh came from coal-fired plant, 29 million from brown coal stations and 11 million from hydro plants. Installed capacity at the year's end was about 25,000 MW, including 15,575 MW in public utility stations, 8900 in industrial power plants and nearly 300 MW in Federal Railways plant.

If power production and installed capacity for 1950 are taken as 100, the corresponding figures for 1959 will be 232 and 221. In other words, power output and installed capacity have doubled within nine years. For 1960, a further rise of some 10% is expected. By 1965, a gross output of 150 million MWh is forecast from an installed capacity of 35,500 MW while the figures from 1975 are put at 280 million MWh and 61,000 MW.

By far the largest electricity consumer is industry. In 1959 it accounted for 60·5% of total national consumption; 63% of total industrial consumption was taken by basic industries (such as iron and steel producers, chemical plants etc.); 16% by mining industries; 11% by capital goods producers (machinery, electric-technical) and the remainder by consumer goods producers etc. Private households used some 10% of the power provided in 1959, trade and business about 6% and transport and public installations 3% each. Internal consumption by the power stations represented 6%, transmission losses also 6% and consumption by pumping stations 1% of total consumption.

Comparatively little has altered in



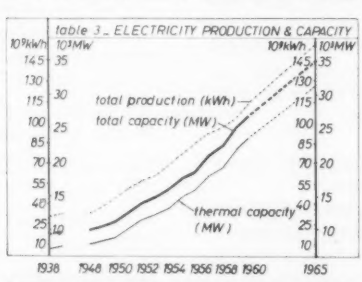
German crude energy consumption, 1950-59 (in million tons, coal equivalent)

this breakdown over the past few years though some shifts have taken place within the various groups. Fundamental changes in the pattern of demand can be deemed improbable for the foreseeable future.

Nuclear power

The development of nuclear power in West Germany to all intents and purposes has so far been restricted to the development of basic science and technology. A nuclear energy programme in the true sense does not exist and the contribution of nuclear power to the country's energy supplies will remain very small in the near future.

West Germany appears to be assured of supplies of conventional fuel under relatively advantageous conditions and there is no urgent need for the rapid expansion of nuclear capacity. Furthermore, there is no military atomic energy programme which would make such capacity desirable. Thus the decisive criterion for the construction of industrial-scale nuclear power stations is whether they are competitive. It is then clear that the development of nuclear energy as a source of power for West Germany will not expand at a rapid pace before nuclear plants prove competitive over wide areas of the country. But as soon as this point has been reached, there will be not only



German electrical capacity and production 1938-65, actual and estimated

an important but a steadily expanding market; at the present time some 2000 MW of new capacity has to be built annually in West Germany and this demand will continue to expand from year to year.

However, now and probably for several years, nuclear plants in West Germany will have power production costs which, compared with the relatively low cost of power from modern conventional plant, are far too high to justify a rapid expansion of nuclear capacity. Even in high production cost areas, a power station producing at a figure of more than four pfennigs per kWh is no longer conceivable. In the modern thermal plants of the Ruhr and the brown coal area of the Rhine, considerably lower power costs are reached—in some cases they are no higher than 2·5 pfennigs per kWh. It is obvious that no nuclear power station can compete with such figures yet.

In cost considerations of this kind, it must of course be remembered that German data cannot be directly compared with those prevailing in Britain or the USA. Because of fairly high interest rates and a comparatively heavy taxation burden, annual fixed costs for a nuclear power station must be reckoned at 15% of the initial capital cost plus ancillary costs, while fuel costs must be allowed for at from 0·7 to 1·7 pfennigs per kWh, according to reactor type. In practice this means that nuclear plants can only hope to compete with conventional stations when their specific construction costs, plus ancillary costs, do not exceed 1400 DM (£117) per kW for low fuel cost reactors and 1000 DM (£83) per kW for high fuel cost types.

Under these circumstances, forecasting the development of nuclear power in West Germany is very difficult. The effect of imponderables in such a forecast is considerable. If steady technical progress unhampered by any reverses is postulated, it can be taken as very probable that reactors which go into operation towards the end of the 1960's—at least in the areas of high conventional power costs such as South Germany, especially between Main and Danube—will, during their lifetime, become competitive with comparable coal-fired plant. It is more difficult to say whether this will happen with oil-fired plant as the fuel oil price trend is much less easy to predict.

Nevertheless, by the early 1970's, at the latest, in many areas of West Germany, nuclear power plants will be highly interesting propositions to meet the need to expand capacity. Even then the amount of fissionable material needed to meet the country's primary energy requirements will remain small for quite some time.

ATOMIC ENERGY
IN THE GERMAN
FEDERAL REPUBLIC

Working on a co-operative basis, with participation by universities, institutes, industry, and the federal and land governments, most of the main research facilities will be ready this year

Nuclear research in Western Germany

by W. H. A. HOCKER, Director of the Federal Ministry for Atomic Energy

APART FROM THE REACTORS built or under construction, for research into nuclear physics about half the universities and technical colleges are equipped with accelerators providing energies up to 3 MeV. In addition to a 5·5 MeV accelerator Frankfurt also has a 35 MeV betatron ; another 5·5 MeV machine is operated at Freiburg. Heidelberg is well equipped both with a 35 MeV betatron and a 12-13 MeV deuteron cyclotron. The Max-Planck Institute for Nuclear Physics, also at Heidelberg, expansion of which is making great strides, will have this year a 10 MeV tandem accelerator.

Both Würzburg and Karlsruhe are equipped with betatrons providing energies up to 35 MeV; the latter also has under construction a 50 MeV deuteron cyclotron. At Bonn, in addition to the synchrocyclotron for 35 MeV deuterons or 70 MeV alpha particles, a 500 MeV electron synchtotron is available for high energy physics research. An even more powerful facility is being built at Hamburg, a 7 GeV sychrotron (DESY) that will be completed by 1963. The estimated cost of some DM.M60 (£M5) will be shared by the Federal Government and the city of Hamburg in the ratio of 85/15. Annual operating costs of some DM.M10 will be shared equally by the Government and by all the states concerned. There are also plans for an 80 cm hydrogen bubble chamber.

On the subject of education, the Atomic Ministry's view is that specialization should come after normal university training in the natural sciences or technology has been completed. Consequently, it gives financial support to the nuclear institutes for subsidizing university trained recruits during their special training period. In 1960, for instance, in the 210 institutes that received Government funds, grants were given to 440 scientists and 280 technologists.

Karlsruhe research centre

The buildings and facilities of the Karlsruhe Nuclear Research Centre (Fig. 1) were built, and are operated, by the Kernreaktor Bau-und Betriebsgesellschaft (KI).

The principal work being undertaken by KI covers research on inelastic scattering of thermal neutrons and on gamma-spectra emitted after neutron absorption ; neutron research with pulsed sources ; research on the inelastic scattering of fast electrons ; preparatory work on the pulsing of sub-critical fast reactor systems ; and the determination of effective cross-sections.

Research Institutes and Facilities

The pattern of nuclear research in the Federal Republic is a co-operative one, with participation by special research centres, universities, institutes, industry, the government and individual states.

Over its five years of existence, the Federal Ministry has provided over DM.M200 (£M17): some 90 institutes and laboratories have been expanded or built, another 120 institutes have received government grants of more than DM100,000 (£8,000) for special equipment, and some DM.M50 (£M4) have been contributed to 175 university establishments for the improvement of equipment and building developments. Financial aid also comes from the various states.

KARLSRUHE RESEARCH CENTRE

Financed by Kernreaktor B.B.: *Institute for Neutron Physics and Reactor Technology; FR2 reactor.*

Financed by GKF:—*Institutes for Radiochemistry; Nuclear Techniques; Radiobiology; Hot Chemistry; Electronics; Solid State Physics, Reactor Materials and Nuclear Physics; School for Nuclear Techniques ; isotope laboratories; 50MeV cyclotron; zero energy Argonaut.*

Isotope Study Company; Institute for Radiation Technology of Foodstuffs; European Institute of Transuranic Elements (1962), *shared with Euratom.*

JULICH RESEARCH CENTRE

Institutes for Reactor Materials; Reactor Components; Radiochemistry; Plasma Physics; Biology; Medicine; Nuclear Physics. Working Group for Isotopic Separation. Dido and Merlin type reactors.

GARCHING REACTOR STATION—Munich Technical High School *Institute for Radiochemistry; Institute for Plasma Physics; FRM reactor; SSW Argonaut reactor (adjacent to Centre).*

GEESTHACHT—GKSS

Institute for Reactor Physics; FRG reactor.

BERLIN—Hahn-Meitner Institute for Nuclear Research. *BER reactor.*

FRANKFURT UNIVERSITY—Institute for Nuclear Physics. *FRF reactor.*

MAINZ UNIVERSITY—Institute for Inorganic and Nuclear Chemistry. *Triga II reactor.*

The Karlsruhe Research Centre showing the buildings of the Institutes and FR2 (top left) (Fig. 1)

The FR2 research reactor, expected to go critical this autumn, will be the main facility. Fuel elements for the first core loading were made in Germany from Canadian uranium. They are aluminium canned with ribs three to four mm high longitudinally. The output of FR2 is limited by the internal uranium temperature of the elements to a maximum of 30 MW. It remains to be seen whether the use of hollow elements, with internal and external canning and internal cooling, will permit a considerable reduction in the uranium temperature and result in a power increase.

The work being undertaken by KII through the various institutes is extensive. In radiochemistry, the main research is on the properties of excess-neutron isotopes of ruthenium and rhodium, as well as of the excess-neutron and neutron-deficient isotopes of cadmium and antimony ; on nuclear reactions ; on the development of processes for the manufacture of radio-nuclides for use as tracers and in measuring gauges ; and on the development of fission product separation processes and the production of labelled compounds.

Nuclear techniques under development include the separation of isotopes by use of high-speed jets (uranium hexafluoride), and the separation of hydrogen isotopes by isotopic exchanges between gaseous hydrogen and water or other hydrogenous compounds using precious metal catalysts.

The work of The Institute for Hot Chemistry is predominantly concerned with the development of liquid/liquid extractor processes in the preparation of nuclear fuel and the separation of fission products ; high-temperature uranium processing and the study of diffusion processes in solids, especially reactor materials and fuel elements.

The 50 MeV cyclotron, under construction by AEG, is expected to be working during the second half of the year. The working group on nuclear spectroscopy will shortly begin research on energy dependence of mass repartition in the fission of heavy nuclei, on the spectra of some cadmium isotopes and on certain fission products. Its initial programme also includes the investigation of alpha activity in the middle of the periodic system. Research programmes are also being drawn up for working groups on nuclear reactions, scattering and neutron experiments.

To develop the use of radio-nuclides in all areas of technology, the Isotope Study Company—a co-operative association of German industrial firms—is building an Institute on the Karlsruhe site. The first construction phase has been completed. It will carry out its own research programme but will also accept research contracts and provide information.

To complement the work of the Federal Research Office for the Preservation of Foodstuffs in Karlsruhe, an Institute for the Radiation Technology of Foodstuffs will be set up at the Research Centre.

In close association with the Nuclear Research Centre, the European Institute of the Transuranic Elements—a facility of the Joint Nuclear Research Organisation of Euratom—will be built by the end of 1962. Its objective will be to explore the potential peaceful applications of the transuranic elements, particularly the use of reactor produced plutonium as a nuclear fuel. Initially it will have a staff of 200, including 50 graduates and the cost of the building and equipment, estimated at DM.M50-60 (around £M5), is to be shared by Euratom and the Gesellschaft für Kernforschung (KII). Operating costs will be borne entirely by the European Community.

Jülich research centre

This facility at Jülich, mid-way between Cologne and Aix-la-Chapelle, is being set up by the State of North Rhine-Westphalia. It serves as the common research centre for the

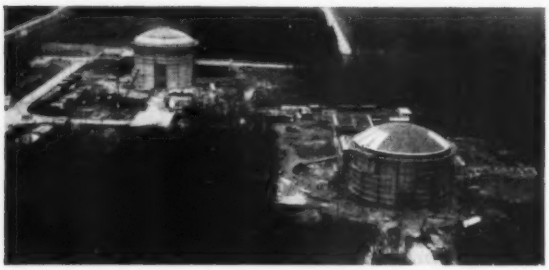
TABLE I Research reactors in the Federal Republic and in West Berlin.

NAME and OWNER*	LOCATION	FINANCED BY	USER*	DESIGNER* (main German contractors)	MAX. NEUTRON FLUX (n/cm²s) MAX. TH. OUTPUT & TYPE	STATUS
FRF Hessen State	Frankfurt/Main	Farbwerke Hoechst AG/ Frankfurt/Federal Gvt.	Frankfurt Univ.-Inste. f. Nuclear Physics	AI (AEG, BBC, Mannesmann, SSW)	$\simeq 10^{13}$, 50-100kW, L54	cr. Jan. '58
BER Berlin State	Berlin-Wannsee	Berlin State/Federal Gvt.	Hahn-Meitner Inste.	AI (AEG, Borsig, Pintsch-Bamag, SSW)	10^{13}, 50-100kW, L54	cr. July '58
FRM Bavaria State	Garching, Munich	Bavaria State/Federal Gvt.	Tech. High Sch., Munich	AMF (MAN)	$1{\cdot}8\times10^{13}$, 1MW, pool	cr. Oct. '57
FRG GKSS	Geesthacht, Hamburg	States of Hamburg, Bremen, Schl.-Holstein, N-Sachsen = 33⅓%; Federal Gvt. = 33⅓%; Industry = 33⅓%	GKSS, Hamburg & Kiel Univs., Hannover Tech. High Sch.	BW (US) (DBW)	$3{\cdot}2\times10^{13}$, 5MW, pool	cr. Oct. '58
FR2 Kernreaktor Bau-und Betriebs GmbH	Leopoldshafen, Karlsruhe	Industry = 50%; Federal Gvt. = 30%; Baden-Württemberg = 20%	Science and industry	Kernreaktor BB (various)	3×10^{13}, 12MW, D_2O	building
FR MERLIN Nordrhein-Westfalen State	Stetternich Forest, Julich	Nordrhein-Westfalen, Federal Gvt.	Bonn, Cologne, Munster Univs.; Aachen Tech. H.S.; Düsseldorf Med. Acad.	AEI-JT (Arbeitsgemeinschaft Stadwerke Düsseldorf)	5×10^{13}, 5MW, pool	cr. May '61
MPR DIDO Nordrhein-Westfalen	Stetternich Forest, Julich	Nordrhein-Westfalen, Federal Gvt.	As for Merlin above	HWP (AEG-Rheinstahl)	$\simeq 10^{14}$, 10MW, D_2O	cr. Nov. '61
SAR-1 SSW	Garching, Munich	Siemens	SSW	SSW (SSW)	$1{\cdot}4\times10^{11}$, 10kW, Argonaut	cr. June '59
SAR-2 Ges. f. Kernforschung mbH	Leopoldshafen, Karlsruhe	Federal Gvt. 75%; Baden-Württemberg 25%	Kernreaktor	SSW Lurgi/Pintsch Bamag (SSW, etc.)	$1{\cdot}4\times10^{8}$, 10W, Argonaut	cr. early '61
AEG Test Reactor AEG	Gross-Welzheim, Aschaffenburg	AEG	AEG	AEG (AEG)	10W, Argonaut	cr. Feb. '61
Triga, Mk. II Rheinland-Pfalz State	Mainz	Reactor: Federal Gvt.; Building: Rheinland-Pfalz & Federal Gvt.	Mainz Univ.-Inste. Inorg. & Nuc. Chem.	GD	4×10^{13}, >30kW, open tank	cr. '62

* For full names of companies see: 'Guide to German Industry', p. 86.

universities of Bonn, Cologne, and Münster, the Technical University of Aix and the Medical Academy of Düsseldorf. Planning, construction and operation is the responsibility of the Gesellschaft zur Förderung der Kernphysikalischen Forschung e.V. (Company for the Development of Nuclear Physics Research) set up in 1953. Its members are the scientific universities of the State and some of the important firms in the nuclear field. The cost of all installations, in which the Federal Government is participating to the extent of DM.M52 (over £M4), are put at DM.M195 (£M16) (1961). (Fig. 2.)

In addition to the Centre's own activities, a Working



The Jülich Research Centre showing the Dido and Merlin reactor buildings (Fig. 2)

Group for Isotopic Separation, which will deal with experimental and theoretical work on the enrichment of uranium by the gas centrifuge method, will work outside the research centre. Other work to be undertaken will cover separation in a centrifugal separating cylinder ; diffusion methods based on porous media ; chemical exchange methods between gases ; distillation methods, and a variety of other novel separation methods based on the mass properties of the materials under study.

Reactor materials research will concentrate on radiation damage and technological irradiation experiments for industrial purposes. Reactor engineering investigations are divided into thermodynamic and flow studies, functional tests of building and machinery groups, out-of-pile loops and other physical research. Facilities for large-scale research projects will include a heating current transformer installation with an output of 2 MW ; an atmospheric gas channel for heat exchanger experiments up to 250°C ; a high-pressure gas channel for the same purpose operating at up to 40 atmospheres and 400°C ; a fuel element test rig for element lengths up to 26 ft. working at pressures up to 60 atmospheres and at temperatures up to 500°C ; and a pressurized and boiling water test rig for experiments up to the point of criticality.

The Radiochemistry Institute is looking at the development of radiochemical processes for the separation, analysis and synthesis of radioactive compounds and is researching on radiation-induced chemical changes, especially with a view to using radioactive recoil to mark preparations.

Garching reactor station

The reactor station of Garching, near Munich, belongs to the Laboratory of Applied Physics of the Munich Technical High School. Its main facility is the Research Reactor Munich, FRM, which was the first German reactor to go critical—on October 31, 1957. Adjacent to the reactor and under construction, is the Institute for Radiochemistry. The station also has a cryogenic facility.

The main studies at Garching are nuclear physics, using slow and fast neutrons, and the effects of radiation on materials. Special attention will be paid to irradiation experiments at very low temperatures (in co-operation with the Commission for Low Temperature Research of the Bavarian Academy of Science), the study of fission products and their diffusion in nuclear fuels, radiochemical research and the production of short-lived radioisotopes for the site, and for affiliated groups, will also be carried out.

The station is working with the Danish centre at Risø on soft gamma spectra emitted after neutron absorption, and with the Karlsruhe Reactor Centre on cross-section research with sub-thermal neutrons.

Next to the station, but separate from it, the Siemens-Schuckertwerke AG have built the Siemens Argonaut Reactor, SAR, for use by their own reactor development section. Also nearby a fusion research facility—the Institute for Plasma Physics—is being set up. This is a research foundation of the Max Planck Company for the Advancement of Science. The Institute works in close co-operation with the Max Planck Institute for Physics and Astrophysics of Munich. The first construction stage will be completed this summer and the total cost, estimated at DM.M60 (£M5), will be met by the Federal Atomic Ministry.

Berlin

The Hahn-Meitner Institut für Kernforschung is a research facility of the State of Berlin and it comes under the control of the Senator for Education, working in close co-operation with the Free University and the Technical College. Nuclear chemistry and Mathematics departments will be introduced this year and a Biology branch is planned. The main research tool for nuclear chemistry, the Forschungsreaktor Berlin, BER, operated at a full power of 50 kW for the first time on January 13, 1960. The teaching programme includes three-week courses on isotope chemistry followed by three weeks practical work.

The research programme of the Institute includes the chemistry of reactor materials, especially organic moderators and coolants ; the diffusion of fission product gases in solid fuel materials (in the framework of the joint US/Euratom research and development programme) ; and the chemical treatment of gaseous and liquid radioactive wastes. Parallel work is being done on activation analysis and on the construction of new radiation monitoring and control equipment.

Other research facilities

The Forschungsreaktor Frankfurt, FRF, which belongs to the University's Institute for Nuclear Physics was presented by Farbwerke Hoechst. The buildings were financed by the Federal Government, the State of Hessen and the city. The Institute is mainly concerned with basic research on neutron and reactor physics, using as equipment a 1·5 MeV cascade accelerator and a 5·5 MeV Van de Graaff generator.

The Institute for Inorganic and Nuclear Chemistry at Mainz University is to have a Triga II reactor. It will aid studies on the properties of short-lived primary fission products, the determination of the yields of primary fission products by direct and indirect methods, research on the influence of neutron energy on fission, and the effects on chemical processes in inorganic and organic systems of intense neutron fluxes and fission fragments.

As a private venture, AEG has built a research reactor of the Argonaut type—the AEG-Prufreaktor—at Gross-Wel-zheim for its own reactor development department.

ATOMIC ENERGY IN THE GERMAN FEDERAL REPUBLIC

'Dynamic stability is guaranteed by a negative temperature coefficient'

Special features of the Brown Boveri-Krupp reactor

by O. MACHNIG, J. BINCKEBANCK, U. HENNINGS and R. KÜSTER, AB BBC-Krupp

THE HIGH-TEMPERATURE gas-cooled 'pebble-bed' reactor for the Arbeitsgemeinschaft Versuchsreaktor (AVR), Düsseldorf, is now under construction. Some of the characteristics arising out of the special features of the design are discussed.

Output control and self-stabilization

Control of the reactor is not based on the use of control rods. Dynamic stability is guaranteed by a temperature coefficient which—because of the high enrichment in U-235 and the on-load refuelling—will be negative in all imaginable operating conditions. This negative temperature coefficient allows the reactor output to be controlled solely through the coolant gas i.e. again without control rods. The shut-down rods foreseen in the design are thus required only for shut-down and possibly to compensate for long-term changes in operating characteristics. The main factor here is xenon-poisoning and this will depend on how impervious the fuel spheres can be made to noble gases. Also, the shut-down rods might be used to bring about possible experimental change in the mean operating temperature.

Power control through coolant flow

This type of control does not allow the coolant exit temperature to be fully independent of power output. Increasing output following an increase in coolant mass flow brings about a drop in temperature. This, however, remains small, and there is no significant change in operating conditions. This effect is also caused by the temperature coefficient and this is obvious since a higher power transfer to the coolant gas demands a steeper gradient inside the fuel elements and a larger temperature difference between element surface and coolant. Since an overall temperature increase is not possible on criticality grounds (temperature coefficient), gradient and temperature must settle at a correspondingly lower level.

Closer examination of conditions by means of perturbation calculation leads to a closed formula for the dependence of coolant gas exit temperature on gas mass flow, which in turn determines the reactor temperature.

The formula is :

$$T_G(H) = T_G(O) + 2\,\frac{T_B{}^0 - T_G(O)}{1 + CM_0\,\frac{8}{3H}\left\{\frac{\rho^2}{R^2}\,\frac{1}{15\lambda\pi f}\,\frac{M}{M_0} + \frac{1}{F\alpha_0}\left(\frac{M}{M_0}\right)^{0.8}\right\}}$$

where :

$T_G(H)$, $T_G(O)$ = coolant inlet and outlet temperatures
T_B = average temperature of the fuel elements under null load
C = specific heat of the coolant
M, M_0 = mass flow of coolant (M_0 maximum output)
H = core height
R = core radius
ρ = fuel element sphere radius
λ = heat conductivity figure for the element material
f = packing factor for the heap of spherical elements (0·61)
F = Surface area of the fuel spheres in a layer 1 metre high
α_0 = Heat transfer figure for a mass flow of M_0.

REACTOR DATA

Thermal output	49 MW
Electrical output	15 MW
COOLANT	
It is anticipated that pure helium will be used. Nevertheless design permits the use of a mixture of helium and neon with a corresponding increase in blower power.	
Temperature to core	200°C
Temperature from core	850°C
Gas pressure in the circuit	10 atm.
Mass flow	13 kg/sm
Pressure drop (total)	750 kg/m²
Blower output	125 kW
As proportion of electrical output	0·80%
STEAM (Single pressure circuit)	
Hot steam temperature	505°C
Hot steam pressure	75 atm.
Mass	55·5 tons/ hr.
Feed water temperature at entry to reactor	110°C
REACTOR CORE (Pebble-bed moving by gravity)	
Diameter	3·0 m
Height	3·6 m
Sphere diameter	6 cm
Porosity	39%
Average power density in core	2 MWt/m³
Heat flow density average	10 W/cm²
Heat flow density maximum	13W/cm²
Maximum heat transfer figure	600 kcal/m²
Maximum temperature gradient between sphere surface and coolant	210°C
Maximum temperature sphere surface	900°C
Maximum temperature inside fuel material	1400°C
Pressure drop in coolant gas	500 kg/m²
Maximum speed inside fuel heap at 850°C	12 m/s
STEAM GENERATOR	
(4 separate sections, forced circulation)	
Diameter	3·5 m
Height	5·5 m
Average temperature gradient between coolant and water/steam	170°C
Maximum temperature of the tube material	560°C
Maximum flow of the gas	9 m/s
Pressure drop of coolant gas	80 kg/m²

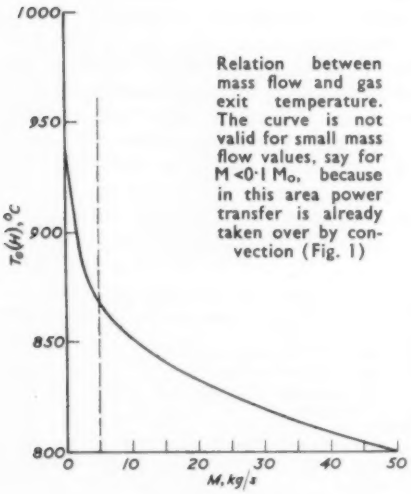
The temperature coefficient itself no longer appears in this equation and this is due to the fact that in the basic approximation, the temperature distribution is obliquely symmetrical with the central plane of the core. This means that local or temperature dependence of the buckling disappears.

In normal operation a power offtake of less than 40% maximum is not foreseen. Figure 1 shows that in this output range, the variation in gas exit temperatures remains by 50°C within the permitted limits for the steam-raising equipment.

In addition to these processes is a further control arrangement intended to deal with the increased xenon-poisoning effect resulting from a rise in power-levels. This, however, takes several hours to become effective and plays a minor role in rapid power-control operations. The importance of its effects will depend, as indicated earlier, on the degree of impermeability of the fuel elements.

Figure 2 shows the characteristic temperature curve of the whole as its results from linking the core and steam raising unit.

The steep graph represents the relationship between inlet and outlet temperatures for the core in various output ranges. These curves vary with height of fuel pile, burnup and poisoning.



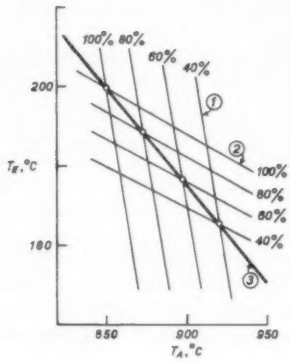
Relation between mass flow and gas exit temperature. The curve is not valid for small mass flow values, say for $M < 0{\cdot}1\ M_0$, because in this area power transfer is already taken over by convection (Fig. 1)

The flattened curves represent the characteristic line field of the steam generator. In Figure 2 a representative case is taken as a basis. Both fields contribute to the characteristic line of the system core-steam generator.

The steam generator

The whole of the steam generator is supended by its own tubes, i.e. by cooled elements, from the inner vessel's top shield. Compensation for heat expansion in the inner vessel is thus not necessary. Only the movements of the two vessels relative to each other are compensated outside the tube penetration points. The number of penetrations could be kept down to 120. Cross-links between tubes (collector, spray cooler etc.) are made solely outside the containment. Furthermore, there are no fittings inside the vessel and—apart from the holding fins on the supporting tubes—no uncooled sections of the steam generator, whose strength would be affected by carburation and embrittlement resulting from contact with graphite at high temperatures and thus imperil the safety of the suspended structure.

Close attention in the construction of this piece of equipment was paid to compactness. To use the circular cross-section above the circular core to the maximum, an involute disposition of the tubes was foreseen. In this layout there is an opening in the centre which is occupied by a central tube. To save space in the vertical plane, the heating surface segments (see Fig. 3) are placed so that the temperature differences between gas and steam are effectively exploited even when operating at partial loads (approach temperatures).

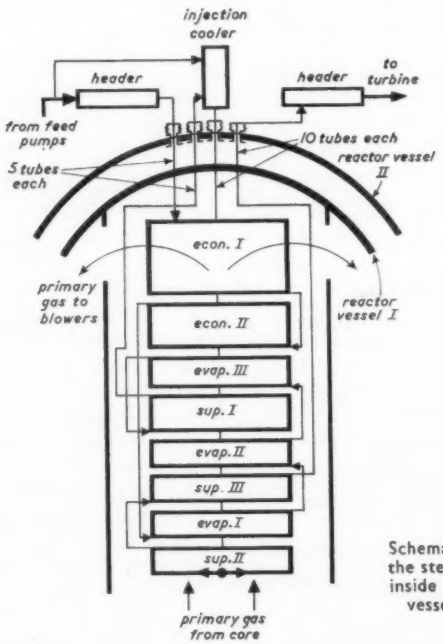


1 Core; 2 steam generator; 3 typical line

Characteristic temperature curve linking the core and steam generator (Fig. 2)

To obtain as near as possible equal heat transfer to all parallel tubes from the gas stream, the direction of the evolvent (involute) is changed for each tube layer so that, looking along its axis, the tubes of two adjacent layers lie crosswise.

In this way, it has been possible to build in a cylindrical space 5·5 m (18·05 ft) high and 3·5 m (11·48 ft) dia. a steam generator producing 55·5 tons/h of hot steam at 505°C and 75 atm. cooling the helium from 850°C to 180°C. Also there is some reserve in hand for the possible blanking off of some of the tubes. Furthermore the heating surfaces have been generously calculated as, so far, the heat transfer coefficients for crossed tube bundles is not known. (The latter has in the meantime been determined experimentally on the basis of



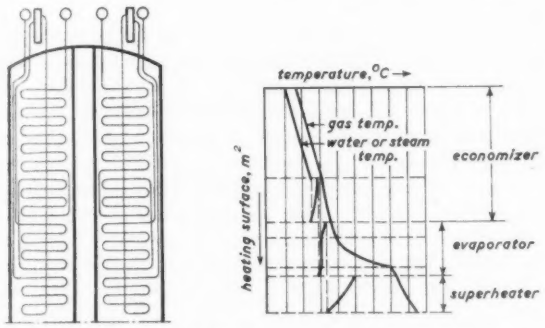
Schematic layout of the steam generator inside the reactor vessel (Fig. 3)

a contract given to the Munich Technical Colleges by Arbeitsgemeinschaft Brown Boveri-Krupp.)

Safety aspects

The water and steam content of all tubes in the steam generator at full operational load amounts to somewhat less than four tons. To keep penetration of steam or water into the primary circuit to a minimum if a tube should fail, the whole steam generator is divided into four parallel and independent sections (see Fig. 4).

When the content of a section empties, the 1000 kg of water (approx.) increase the total pressure in the reactor vessel by about 5 atm. to 15 atm. (The inner vessel is so designed that internal pressure can rise to 30 atm. on condition that external pressure in the secondary vessel remains around 10 atm.) It is intended under these conditions to cool down the reactor with the help of the three undamaged sections, thus protecting the tubes of the failed section from overheating and carburation. As soon as the defective tube



Temperature course in the steam generator (Fig. 4)

has been found, it is closed off by welding at each end. It is not proposed to replace defective tubes and the excess heat exchange surface capacity will take care of this.

Possible operational dangers to the reactor containment vessel as a result of increasing internal pressure due to water penetration are to be the subject of further studies. It is obvious that after a tube failure the important thing is to prevent further supply of water to the leak. The high heat capacity of the graphite and carbon bricks around the core is adequate to vaporize large amounts of water. The defective section must be rapidly detected and isolated.

Signals are emitted of various pressure measurements in a pre-determined order when pressure rises. If in spite of the various independent detectors and their various linkages with the switchboard (electrical, pneumatic fed by the pressurized air circuit and pneumatic fed by the blanket gas) the pressure inside the first vessel should continue to rise, then safety valves will open at the limiting pressure to blow over the gas/steam content to a pressure vessel in the secondary container equipped with a cooling water system (emergency cooling vessel) so that even in this case there is no contamination of the secondary vessel or a pressure increase. Very small leaks in the tubes—hair leaks—will very quickly be discovered by detectors which analyse the coolant gas for carbon monoxide and hydrogen.

No effect on the external safety of the reactor can result from a pressure increase in the internal pressure vessel. On the other hand, there is the possibility, that gas might penetrate through the defective tube and reach the turbine house through the secondary circuit. A primary condition for this is that the pressure in the steam generator should have fallen to about that inside the reactor container. The path to the turbines is barred by a pneumatic three-way valve behind the high temperature steam collector for each section—which also provides for pressure relief in the steam generator should there be a tube failure—and the valve switches the gas/water stream to the emergency container. Furthermore, independently, a sliding plug closes the steam pipe if pressure falls to the level where gas can penetrate. A third safety measure is the closing of a pneumatic valve in the hot steam collecting duct behind the main steam collector if pressure drops to the maximum primary pressure.

To deal with possible leakage through the seals of the turbine stop valves, air or water under pressure can be introduced into the pipeline. The safety valve between three-way valve and emergency condensing container also closes when pressure drops to the maximum primary gas pressure to avoid unnecessary contamination of the container.

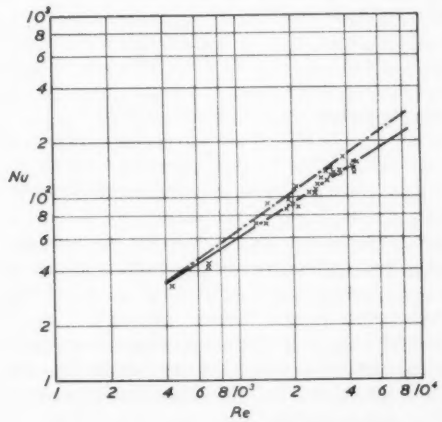
A further feature of the steam generator in the AVR reactor is the necessity that it should be completely leak-proof to prevent even the smallest amounts of water entering the primary circuit. Because of the high operating temperature, the reaction between water vapour and graphite (*2*) is not negligible and can adversely affect the operation of the steam circuit because of carbon dioxide attack on the tubes.

In view of the UK experimental results and the disposition of primary gas and decontamination circuits, only a very small amount of water leakage can be tolerated. To reach the required degree of leak-tightness, the whole steam generator—plus allowances for measurement and calculation—must let through only 1×10^{-6} l/s using as reference helium at 1 atm. compared with a vacuum, as room temperature. With current testing methods, this is possible.

Heat transfer in the reactor

Calculation of the temperature in the various sections of the reactor was carried out with the well-known heat transfer correlations for which generally adequate data are available. On the other hand little research had been done on heat transfer from a heap of heat-radiating spheres to a gas passing through it. Major parameters here are the average temperature of the fuel elements as well as the solution to the question of how temperatures vary in a heat-producing randomly-packed fuel heap.

In principle it is possible to heat either one or all of the fuel spheres and measure the temperature of the gas. But in



Heat transfer to air in the pebble-bed (Fig. 5)

both cases heavy experimental costs would be involved. For this reason, BBC-Krupp chose another method, that of determining heat-transfer by analogy with mass transfer. In the experiments, a number of moth balls (naphthalene spheres) were incorporated in a heap of fire clay spheres. The heap was traversed by an air blast. After a predetermined period (about 5 h) the naphthalene spheres were removed and their weight loss measured (about 8%). In this way, heat loss can be measured and variations in heat transfer according to the statistical differences in the positions of the individual elements can be determined.

For air, the mean relationship is :

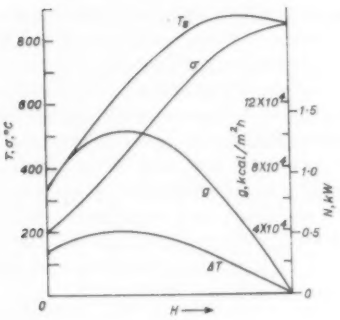
$$Nu = 0{\cdot}65 \times Re^{0{\cdot}65}$$

The allowance for gases with a different Prandtl number gives :

$$Nu = 0{\cdot}77 \times Re^{0{\cdot}65} \times Pr^{0{\cdot}5}$$

In this the Pr-dependence is taken as the power 0·5 for gases with $Pr < 1$ in contrast with most of the data hitherto available which postulated a power of 0·3 for various media.

Figure 5 gives the mean values obtained in a number of



Temperature rise of fuel elements and coolant gas calculated over the height of the fuel heap (Fig. 6)

experimental runs, the points representing results for spheres inside the heap subjected to air flow.

In the same figure there is a straight line giving the results of the formula established by us and a broken line representing the formula established by Denton (*4*) :

$$Nu = 0{\cdot}58 \times Re^{0{\cdot}7} \times Pr^{0{\cdot}3}$$

The mean variation of the heat transfer number throughout the whole fuel heap is $\pm 5\%$; the largest measured deviation from the mean value was 17%. As it is known that the temperature difference between the element surface and the coolant gas is inversely proportional to the heat transfer number, these small variations are valid for the anticipated temperature gradients.

The known heat transfer relationships are generally valid only where there is a relatively small difference in temperature between heating surface and gas because of the close temperature-dependence of the values for solids.

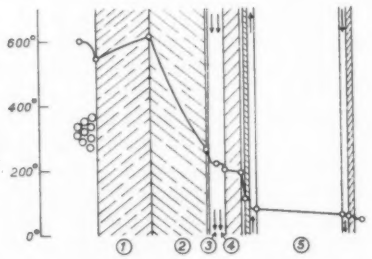
With the density of heat flow in the case under consideration and the resulting large temperature differences in the reactor gas, variations from this relationship can be anticipated (*5*).

Figure 6 shows the variation of the temperatures T_S of the fuel element surfaces/coolant gas calculated over the height of the fuel heap H. The density of the heat flow stream is g also represented as the thermal output, N, of each fuel element. $\Delta T = T_S - \sigma$ is the mean temperature gradient between fuel element and coolant gas. Maximum temperature inside the spheres in the core of the fuel elements is about 1400°C at full operating load.

In the construction of the reactor, special attention is being paid to the fact that all the steel components must operate at temperatures under 600°C. In this way danger of carbon pick-up by the steel will be minimized. The coolant gas, after leaving the steam generator at 180°C, is led through a cylindrical gap between pressure vessel and reactor casing, flowing over the thermal shield. For most of the components – except the steam generator—temperatures in all reactor operating conditions will thus be kept considerably below 300°C (Fig. 7). In this way, for instance, ordinary steel can be used for the pressure vessel. To obtain only a small temperature gradient for the first biological shield (heavy concrete) and to maintain as closely as possible normal operating temperatures should there be a steam generator fault, a circulation of blanket gas between the two containment vessels will be necessary.

In the graphite reflector, radiation absorption and insulation from the coolant gap by the carbon bricks causes a slight rise in temperature. This prevents any significant build-up of Wigner energy, even in the lower and cooler areas of the reflector.

As already stated, the absorber rods are not to be used for control but only for shut-down of the core and in emergencies (scram action). In normal start-up of the installation the reactor can be left just critical under nil load and the heat produced by the chain reaction is balanced by that lost to the steam generator and the reactor walls. To keep this loss as low as possible, the natural circulation of the coolant gas is stopped by closing the main gas duct valves and the reactor will remain hot critical without cooling from the blowers. In the first few days after shut-down the average core temperature will rise from 650°C to 850°C through fission product decay heating until the declining residual heat comes into balance with heat losses to the reactor walls. The possibility of keeping the reactor critical without coolant circulation represents an important safety factor in cases of operational stoppages and makes operation much simpler.



1 Graphite; 2 carbon bricks; 3 coolant gap; 4 thermal shield; 5 concrete

Temperature drop across the reactor containment and shielding (Fig. 7)

By raising gas pressure and blower output, the power output could be increased several times while maintaining the same overall dimensions. Before this step, however, operational experience of the behaviour of the prototype reactor at high temperatures, the diffusion of fission products from the graphite-canned elements, the purification of active coolant gas and the uranium/thorium breeding cycle with a view to obtaining optimum fuel utilization.

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ATOMIC ENERGY
IN THE GERMAN
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This plant has been designed to provide a flexible instrument for studying performance under all types of **BWR** *operation*

The Kahl Nuclear Power Station:

zero power tests and planned modifications

by Dr HANS-JOACHIM BRÜCHNER, AEG-Kernenergieanlagen, Frankfurt/Main

THE BUILDING LAYOUT of the Kahl Station is shown in Fig. 1, which is a recent photograph. The reactor, the complete primary circuit and related auxiliary systems are located in a gas and pressure tight steel enclosure, the reactor containment. Active wastes are treated in a separate building which also houses the storage pool for spent fuel elements as well as a locked compartment for storage of unirradiated fuel elements. The burial pits for disposal of solid and liquid wastes also belong to the control area of the plant. The non-active zone comprises the service building with offices, laboratories and workshop, the control room building annexed to it and the turbine building with the secondary cycle and related auxiliary systems. For further information see refs. (*1–4*). When the plans for plant power increase are implemented, this turbine building will be extended towards the River Main in order to accommodate the second turboset.

PROPOSED PLANT EXTENSION

Germany's first nuclear power station has a 15 MWe light water natural circulation BWR, which went critical on November 13, 1960. Provision has been made for doubling the design power and changing to forced circulation; the second turboset may then be operated in a direct cycle.

Figure 2 shows a simplified heat flow diagram and is essentially self-explanatory. 118·5 t/h of saturated steam are produced in the reactor at a thermal power rating of 55·5 MW and at a pressure of 71·3 atm and transmitted to the steam transformer. The condensate is subcooled to 227°C in the condensate subcooler and then returned to the reactor pressure vessel, where it mixes with the water which has not been evaporated while rising through the coolant channels. Secondary saturated steam of 105 t/h at 47·8 atm is produced and dried in the steam transformer and sent to the AEG wet steam turbine. Since in a BWR reactor pressure must be maintained in spite of sudden load trips, excess secondary steam can be bypassed directly to the condenser, which has a vacuum of 0·035 atm and which is cooled by 4200 m³/h of River Main water. Preheating of condensate and feed water is carried out in the usual manner. A number of auxiliary systems supplement the primary circuit; one of these, namely the bypass water purification system, can be seen in Figure 2.

MAIN COMPONENTS

It should first be mentioned that the design of plant components that contain or are likely to contain activity at high pressure and/or temperature was generally based on either the German code (AD-Merkblätter, DIN-norms etc.) or the ASME Boiler and Pressure Vessel Code, Section VIII, whichever code rule would guarantee the greatest safety. The Technischer Überwachungs-Verein (TÜV) of Bavaria was charged with checking whether all relevant code rules had been observed. Apart from that, the TÜV as a neutral and independent organization was also responsible for testing of materials as well as of workshop and on-site construction of such plant components.

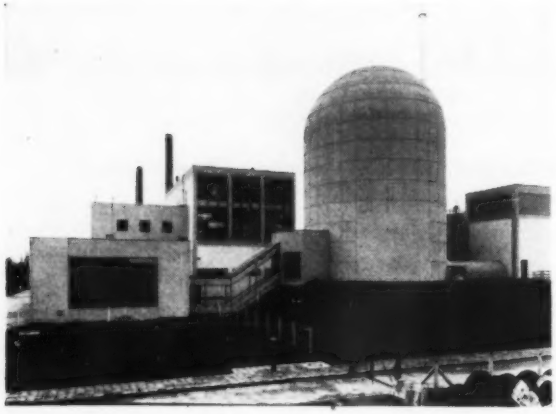
Reactor pressure vessel

The reactor pressure vessel was fabricated by the Mannesmann Hüttenwerke AG of Duisburg. It is cylindrical in shape, its dimensions being 2438 mm (8 ft) inner diameter and 8230 mm (27 ft) inner height. The weight, including the lid, is 103 tons.

The bottom is hemispherical, thus ensuring that at system pressure the axes of all 21 control rod nozzles penetrating the bottom remain parallel to the vessel axis. The lid, having the same inner diameter as the vessel, is connected to it by 44 bolts of 105 mm (4·13 in) diameter, which will be heated

for fastening and unfastening of the lid such as to avoid torsional stresses. The gasket is formed by two concentric metal ring seals, designed to sustain repeated lifting and lowering of the lid as well as repeated temperature and pressure changes. Both sides of the gasket seat consist of an overlay welded and hardened nickel alloy with polished surface. All nozzles were designed such as to keep thermal stresses at welding joints as low as possible if feed water entering the vessel were colder than its walls.

The plant extension up to about 30 MWe, now being contemplated, has been taken into account in the following way: the steam outlet and condensate inlet nozzles have been designed for double flow rate, each with 350 mm (13·8 in) internal diameter. Four nozzles of 457·2 mm (18 in) i.d. have



Photograph of plant taken after completion; reactor building in centre; turbine building, control room annex and services building towards the left of reactor building; building for waste treatment on the right (Fig. 1)

been provided for the installation of two forced circulation loops; they are at present blind-flanged. Provision has also been made for adjusting reactor internals such as thermal shield and baffles as well as orifices for coolant flow. Apart from a redesigned core, no further change in the reactor pressure vessel is believed to be required for the power increase planned for the future.

The design and operating data for the pressure vessel are:

operating pressure	71·3 atm
operating temperature	285°C
design pressure	89 atm
design temperature	343°C
test pressure	133 atm
maximum thermal stress due to irradiation at core midplane	2·3 kg/mm² (1·46 tons/in²)

Thermal stresses in addition to those induced by irradiation will be kept within permissible limits by adhering to the operating manual. The minimum permissible time for the reactor to attain operating temperature from ambient temperature or vice versa is six hours.

The pressure vessel, i.e. cylindrical part, bottom and lid, is made of plated steel sheet with 98 mm (3·86 in) wall thickness and 6·5 mm (0·24 in) plating. The base material for the vessel, flanges and nozzles of more than 150 mm (5·9 in) i.d. is carbon steel type 19 Mn5 with 0·4–0·6% Mo and a Co-content of 100 ppm only. This type of steel corresponds to ASME type 302 B, which has been tested extensively under irradiation. The plating consists of Nb-stabilized stainless steel type 4550 (X10 CrNiNb 189), being overlay welded with the base material at nozzle joints. Nozzles of 150 mm (5·9 in) i.d. or less are fabricated entirely out of this steel type. The bolts to fasten the lid flange are made of steel type 21 CrMoV 511, their nuts of 24 CrMo5.

Steam transformer and condensate subcooler

The steam transformer was fabricated by the Gutehoffnungshütte AG, Sterkrade, and is of the vertical tube-bundle type with fixed tube sheets. Primary steam flows through the shell side so that non-condensable gases like hydrogen and oxygen being formed by radiolysis can be tapped off easily before treatment in the off-gas-system. Secondary feed water at steam saturation temperature rises in the tubes and returns to them through external downcomers by natural circulation. Secondary feed water is evaporated and dried in a chamber above the upper tube sheet; steam-water separation is accomplished in a coarse and a fine stage, i.e. by a centrifugal and a deflection separator. Figure 3 shows the assembly of the steam transformer in the reactor building.

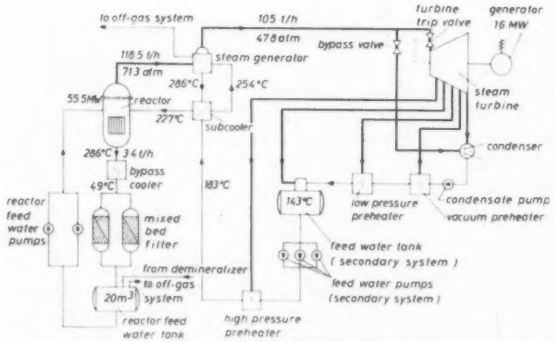
The condensate subcooler was fabricated by the Vereinigte Kesselwerke AG, Düsseldorf, and is a horizontal U-tube heat exchanger with two separate tube sheets, thus reducing thermal stresses in a much better way than in case of a single tube sheet. The primary condensate passes through the tubes, whereas secondary feed water flows through the shell side.

All parts in contact with primary circuit water are made out of or plated with corrosion-resistant stainless steel of the 18/8 Cr-Ni type. The steam transformer tubes, however, consist of corrosion-resistant ferritic steel (X8 CrNiMo 225), which possesses the same thermal expansion coefficient as the shell material, thus minimizing thermal stresses to the greatest possible extent. Figure 4 shows the assembly of the condensate subcooler in the reactor containment.

SOME SAFETY ASPECTS

The various assignments of the Technischer Überwachungsverein (TÜV) have already been mentioned. In addition, the TÜV was also charged with reviewing all safeguard provisions of the Kahl Nuclear Power Station. The Bavarian licensing authorities have required the TÜV to procure an expert opinion, on which the authorities could base their decision with regard to the operator's application for a construction and an operating license.

It was not until 23 December 1959 that the much publicized Atomic Law of the Federal Republic of Germany was enacted and proclaimed. Together with an Amendment of the Federal Constitution, this Law brought about a change in



Principal heat flow diagram (Fig. 2)

the licensing procedure in that it is vesting the Federal Government with the power of licensing, whereas the formerly solely competent state authorities must now execute its rulings.

Among other things, this new legal situation had the consequence that, in addition to the TÜV, the Reactor Safeguards Commission also had to review the hazards summary reports. Thus, Kahl Nuclear Power Station has had a twofold full scale nuclear safety review and inspection. Apart from the TÜV and the Reactor Safeguards Commission, many other authorities and boards participated according to their competence in every phase of the licensing procedure.

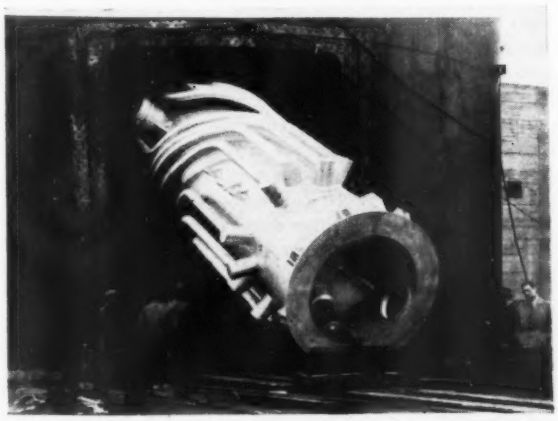
As a specific example of the safeguard aspects of the Kahl Station, the reactor containment design is selected, because the contemplated plant extension has an important bearing on it.

Design of reactor containment

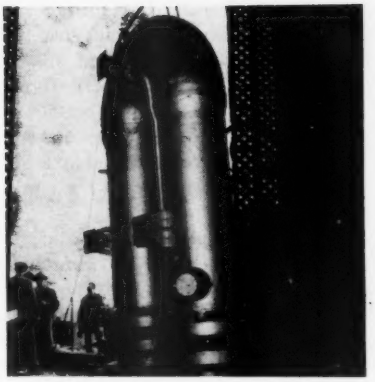
As is well known, the reactor containment must be designed so as to prevent to the greatest extent possible the release of fission products and other radioactive fuel components to the atmosphere external to the reactor containment in the event of the highly improbable accident of fuel canning and primary circuit rupture. Therefore, the safety barrier formed by the containment shell must be capable of withstanding the excess pressure that would be built up in the inside in the course of the concomitant release of all the energy stored in the primary coolant medium, possibly enhanced by additional energy releases due to a nuclear excursion, chemical reactions and later dissipation of decay heat.

As to the Kahl Nuclear Power Station, the reactor containment was designed for an internal excess pressure of 5·5 atm at a temperature of 155°C. These values already include the allowance to be made for future plant extension, since for the present plant power of 15 MWe only a maximum excess pressure and temperature of 3·43 atm and 135°C respectively must be expected, regardless whether the post-incident cooling system for the reactor building would operate or not.

Since the containment dimensions (cylinder with hemispherical dome and bottom) are overall height 46 m (151 ft), 20·50 m (67·2 ft) of which is below ground level, and outer diameter 13·7 m (44·9 ft), this then leads to a wall thickness of 21 mm (0·827 in) in the cylindrical part and 12 mm (0·472 in) in the hemispherical parts for the type of construction steel used (Ruhrstahl BH 38 KW/KA, equivalent to 17 MnAl3).



Steam transformer being assembled in containment (Fig. 3)



Condensate subcooler being assembled in containment (Fig. 4)

The successful pressure test was carried out in March 1959 at a test pressure of 6·8 atm gauge under ambient temperature, this value being the 1·1-fold design pressure times the yield point ratio. The leakage rate was measured at design pressure for 48 h with all penetrations blind-flanged. It turned out to be less than 0·25 vol %/day, which is believed to be the best technically attainable limit.

The reactor containment rests in a caisson, which is lined with a water proof insulation to seal against ground water. All entrances to the building, i.e. personnel air lock, emergency air lock, materials air lock and temporary assembly opening, are located above an earth heap of 3 m (9·8 ft) above normal ground level. This protects against floods so that there is only one chance in a thousand years that the Main level will ever reach the sills of the containment entrances. Also the containment has been surrounded by a 70-cm (2·3 ft) layer of concrete to provide adequate shielding for the environment against direct radiation emanating from a cloud of air-borne activity that may be hovering in the building in the event of an accident. Below this layer of concrete there is a 5-cm (2 in) layer of glass wool for thermal insulation.

Figure 5 gives an idea of the arrangement within the containment building. There are five floors connected by a stair case, which is the shortest possible escape route in emergency. The reactor vessel is installed eccentrically, thus providing enough space to accommodate the forced circulation loops and possibly another steam transformer as well as condensate subcooler if, unlike at present envisaged, the plant power were to be increased in an indirect rather than direct cycle.

ZERO POWER TESTS

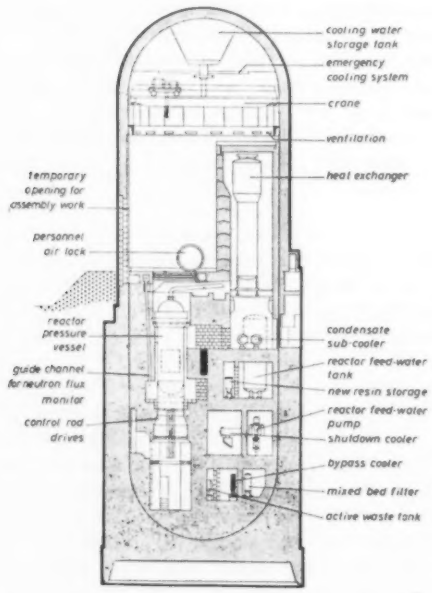
These were carried out under the responsibility of AEG with the aid of the future plant operator VAK (Versuchsatomkraftwerk Kahl GmbH), and of the US General Electric Company in three phases within a period of one month, i.e. from Nov. 11 until Dec. 11, 1960. To facilitate understanding of the work done in each phase a brief description of the reactor core, designed by GE will be given. The full operational core consists of 88 fuel elements. Each element is a square assembly of 36 fuel rods and surrounded by a guide channel, which is normally of zircaloy-2 apart from the beginning of the first fuel cycle, when Zr-2 is replaced by slightly borated stainless steel in 60 channels in order to compensate the initial excess reactivity. Each fuel rod, average diameter of 14·45 mm (0·569 in) and cold active length of 152·4 cm, is made up of two segments and clad by

Zr-2. The fuel material consists of UO_2 pellets (average density 95% theoretical), enriched to 2·3% U-235 apart from the first core charge, half of which being enriched to 2·6% U-235. There are 21 cruciform control rods, which enter the reactor vessel at the bottom and which have poison sections of 2% boron steel, the total stroke of each rod being 152 cm (5 ft). For reactor start-up a Sb-Be neutron source is being used. Further data on the core can be found in the references.

The first phase included the loading of the minimum critical core charge and reactivity measurements therewith. The approach to first criticality was carried out in the usual manner by plotting the reciprocal of neutron flux readings against the number of elements loaded. The minimum critical core charge was found to consist of 29 elements with stainless steel channels, 16 elements having 2·3% and 13 having 2·6% U-235 enrichment. With this charge and with all control rods fully withdrawn a period was observed at a reactor temperature of 38°C that corresponded to an excess reactivity of $0{\cdot}13096\Delta k$. To measure the temperature coefficient of reactivity with this core loading the water in the reactor vessel was heated up to 74°C by steam coming from the adjacent RWE thermal power station of Dettingen. By correlating the temperature against time and reactivity against time curves a positive temperature coefficient was obtained for the temperature region observed and for all control rods but one fully withdrawn. To determine the void coefficient of reactivity, another fuel element was loaded, and a fuel element of either 2·3 or 2·6% enrichment was especially prepared by suspending small plastic tubes into the spacings between its fuel rods so that the water in them could be displaced by pressurized air. Then two period readings were taken, both with water and with air in the tubes. Depending on the enrichment and lattice position of the void-fuel element the reactivity coefficient turned out to lie in the range between -10^{-4} and $-10^{-5}\Delta k/\Delta V$ with a volume change corresponding to 10%.

In the second phase of zero power tests the minimum critical core charge was completed to the full operational core in several steps, each time determining the safety margin available for shutdown of all control rods already belonging to the core. For the full operational clean and cold core this safety margin amounted to $7{\cdot}7\%\Delta k$. The void coefficient of reactivity for the full core was of the same order of magnitude as quoted above. The temperature coefficient of reactivity was now measured in the range from 38°C up to 85°C, both at rising and falling temperatures. At the lower end of this range it was again positive, but it turned negative in the temperature region between 63° and 75°C, depending on the particular control rod configuration. To conclude this phase of the zero power tests several control rods were calibrated, and critical control rod configurations were determined. It was found that three control rods of a central group of four had to be withdrawn fully, while the fourth rod had to be inserted partially.

In the third and last phase the sequence was established according to which control rods are to be withdrawn from the core in the normal approach to criticality of the full operational core. Also the rate of reactivity change upon withdrawal of any rod of the central group was measured. The largest value was found to be $0{\cdot}79\times10^{-3}\Delta k/s$ for a configuration in which the central rod was partially inserted and the four rods surrounding it were fully withdrawn. Finally the microscopic and axial neutron flux distributions in a few selected fuel element assemblies were determined by activating Mn-Cu alloy wires. The results obtained clearly exhibit the effects expected by theory with regard to the irregularities in the fuel-moderator lattice.



Longitudinal section of reactor building (Fig. 5)

CONCLUSIONS

A few remarks remain to be made with regard to the plant extension contemplated for a later phase of construction. This plan was actually induced by the operating experience of EBWR and VBWR, in the course of which the potential of the BWR type for considerable power increase was successfully demonstrated. For the Kahl plant it is hoped to extract as much as twice the present power out of the same reactor vessel. This is tantamount to the requirement of adequately redesigning the reactor core so that twice the present mean power density can be attained, this being only 24 kW/l of core volume. This is believed to be possible in principle, since average power densities of the order of 50 kW/l at the same reactor pressure as the Kahl reactor have already been achieved sometime ago in the VBWR with certain fuel element types and with stable natural circulation. Nevertheless, more development efforts are still being spent to find out which core design will eventually be the most economical for this purpose.

Apart from that, the work remaining to be done is straightforward, if the plant extension is to be implemented in the manner currently envisaged, since all necessary provisions for the installation of forced circulation loops and of another power extraction cycle, either direct or indirect, have already been made. There exists some likelihood, however, that the present plan for plant extension may eventually be adjusted to include some provisions for nuclear superheat.

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The project has both long-term and short-term goals

The Siemens Multi-Purpose Reactor Design

by Dr ALBERT ZIEGLER, Siemens-Schuckertwerke AG, Reactor Development Dept., Erlangen

CONSIDERING THAT THE natural uranium D_2O reactor is, generally speaking, an attractive concept it was decided some years ago to initiate a programme by developing a pressure-vessel reactor. Preference was given to a pressurized water type for which the largest amount of reliable information was available. In designing firstly a 100 MWe reactor it was realized that this type would be very suitable for fuel testing under high temperature conditions. On the other hand we felt that a high flux testing reactor was urgently needed in Germany for further reactor development work for different industrial groups. Knowing this the design was changed to a 50 MWe power producing and fuel testing reactor, which was offered to the Federal Minister for Atomic Power. This reactor, known under the designation MZFR (Mehr-zweck-Forschungsreaktor) has some characteristics which, for a prototype, are somewhat unusual. While the size of 50 MWe is too small to be economic, an appreciable share of the expenses can in any case be covered by the energy produced. In addition, the plant is to serve for testing fuel elements and reactor materials and is, for these purposes, equipped with special facilities. Since only the balance of costs has to be borne by the use of the test loops, the reactor should prove to be a rather economical testing reactor, together with experience in power reactor operation.

REACTOR DATA

Type: D_2O moderated and cooled, natural uranium	
Thermal output	200MW
Turbine power	55MW
Inlet coolant temp.	252°C
Outlet coolant temp.	280°C
Fuel	UO_2 pellets
Canning	zircaloy
Mean thermal neutron flux	1.2×10^{14} n/cm²s

RESEARCH AIMS

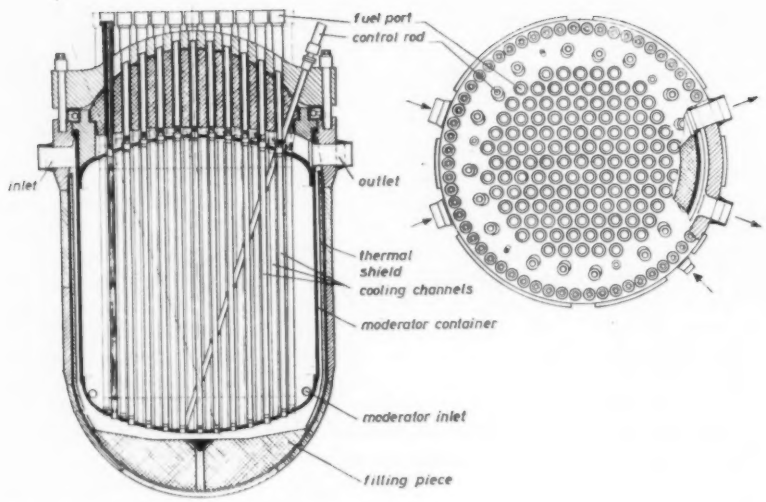
Tests of natural uranium power reactor fuel elements under operating conditions
In-pile loop research on coolants
Material testing
Behaviour of heavy water as coolant and moderator during operation
Research leading to the introduction of the Th-U-233 cycle
Production of radioisotopes
Production of fissile materials for future reactor
Tests on new construction designs

It was realized from the beginning that the largest vessel which could be welded and machined in a workshop and transported by rail would have to be used, since the reactivity margin was definitely the crucial point and decisive for the quality of the reactor. Having fixed the vessel diameter the optimal arrangement of a natural uranium core fitting into the vessel and representing the best possible compromise between excess reactivity and power costs had to be decided.

REACTOR DESIGN

The lay-out of the reactor is shown in Fig. 1. In a pressure vessel of 4·1 m (13·45 ft) inner diameter a second, so-called moderator container of 3·8 m (12·5 ft) inner diameter is suspended. It is penetrated by a hexagonal lattice of vertical shroud tubes which constitute 121 coolant channels and connect the inlet chamber below the moderator container with the outlet chamber above it. As the shroud tubes are insulated by layers of stagnant water the moderator can be kept relatively cool. Each shroud tube consists in the core region of zircaloy-2, and outside the core of stainless steel. The upper ends are fitted into corresponding openings in the pressure vessel lid which are leak-tight sealed by special high-pressure closures. These allow both the fuel elements and the shroud tubes to be withdrawn through the openings.

The coolant from the two main circuits enters the reactor vessel and flows downwards through the cylindrical gap formed by the walls of the moderator container and the pressure vessel along both sides of the thermal shield into the inlet chamber where it is distributed to the different coolant channels. The channel openings are equipped with orifices, the diameters of which are chosen so as to adapt the coolant velocity pattern to the radial power density distribution, ensuring the exit temperature to be the same for all channels. The coolant passes from the outlet chamber through two pipes to the steam generators after leaving the channels



Section and plan of the multi-purpose reactor (MZFR), this is the new designation for the modification of the SNDR 1b (Siemens-Naturanium-D_2O-Reaktor) 1b indicated that it was a pressure vessel type with the fuelling machine outside the vessel (Fig. 1)

through longitudinal slots at the upper end of the fuel section.

A small part of the coolant flow is cooled to a lower temperature and pumped back into the moderator container, where it is distributed uniformly by a sparger close to the bottom. The water, while it rises slowly between the coolant channels, is heated up to 100°C or more above the inlet temperature. It then leaves the moderator vessel through several openings in the upper part of the cylindrical wall for the outer ring-shaped gap, where it mixes freely with the entering coolant flow.

The free space in the upper and lower part of the vessel is occupied by fillers, conserving heavy water and greatly reducing the radiation level, particularly at the top.

FUEL ELEMENTS

Each channel holds a couple of fuel elements joined together and a filling piece by which the upper element is attached to the top seal. The connexion is accomplished by special couplings. As shown in Fig. 2, each element consists of a bundle of 37 rodlets each of which contains UO_2-pellets enclosed in a zircaloy tube of 10·5 mm (0·976 in) inner diameter and 0·6 mm (0·056 in) wall thickness. At either end the rodlets are fixed in plates, and spacers are provided along the elements at a distance of about 30 cm (28 in) from each other.

CONTROL RODS

For control and shut-down purposes, but not for shimming, seventeen absorber rods are provided. These consist of corrosion-resistant Cd-In-Ag-tubes of 60 mm (2·36 in) outer diameter. They are arranged obliquely and penetrate the vessel lid near the periphery, leaving the middle part above the reactor free for moving the fuelling machine. The inclination of the control rods is only 20°, so that they are sure to drop by gravity, when not energized. The control rods are moved by specially developed magnetic jacks, the shut-down movement by gravity being accelerated by a loaded spring placed at the upper end of the control device. Since the shimming of reactivity changes due to burnup and Xe-poisoning is accomplished by variation of the moderator temperature, one single rod will suffice for control purposes while the other rods are merely safety rods.

FUEL LOADING SYSTEM

The reactor and the fuelling machine are designed for refuelling under load. The procedure is as follows. The 7-m (23-ft) long fuelling machine suspended in a carriage is moved over a certain element position and lowered on to the closure head. A sealing ring is then pressed down against a sealing face by the heavy weight of the machine, about 20 tons. A magazine drum inside the machine has five axial receptables, two of them being designed for holding fuel element columns, two others equipped with special tools for handling the closure, and the last one containing a reserve closure. The vertical movement of all parts is effected by a spindle and ball nut. After the closure has been unscrewed by a special key, another key is fitted into the head piece and locked. Then the whole fuel element column can be lifted and drawn up into the drum magazine. A new fuel element column is then swung into the position and lowered into the reactor core. A third key is used to lock the seal by screwing it home. After pressure release and leak testing the machine can be lifted and moved over to the shuffling machine. As the fuelling machine has its own cooling circuit it is possible to hold its temperature below 100°C.

It should perhaps be mentioned that not only normal, but all types of water-cooled test elements can be handled equally well by the same fuelling machine.

In the re-shuffling machine the elements can then be disconnected by simply turning the rotary drum and rearranged so that the lower element comes to the top and the upper to to the bottom whereupon the re-shuffled column is taken over again by the fuelling machine. A completely burnt fuel element column, after having been replaced by the re-shuffled one is carried by the fuelling machine to the fuel element lock, where it is dried, so that no heavy water is lost, and deposited in the fuel-storage pit. If the burnup amounts to 4000 MWd/t, as is expected, such a loading procedure has to to be done every 24h, preferably at night, as the reactor power has to be lowered to 80%.

INSTRUMENTATION

For neutron flux measurements eleven ionization chambers outside of the pressure vessel are provided, each of them being enclosed by specially arranged reflector material. Four uncompensated ion chambers are arranged around the reactor, at angular displacements of 90°, to indicate any deviations of the neutron flux distribution from the regular cylindri-

cal symmetry. Three of these chambers are used in a two-out-of-three-system to establish the existing value of the neutron flux for the control system, the fourth being held in reserve. Also, three compensated chambers for the low-power range are connected to logarithmic channels to measure the reactor period. Independently three other ion chambers are provided in a two-out-of-three-system for safety purposes, one again being kept in reserve. For the initial start-up a neutron source and Geiger counters have to be used, but after a short operating time this is no longer necessary, as the photoneutron production in D_2O will create a neutron flux density of the order of $10^6 n/cm^2 s$.

While inside the pressure vessel the neutron flux will not be measured provision for temperature measurements is made at the exit of forty coolant channels and at twelve important points in the moderator by means of special thermocouples. Additional thermocouples are installed in the inlet and outlet ducts, and are accessible for maintenance; only these are used for control purposes.

PRIMARY CIRCUITS

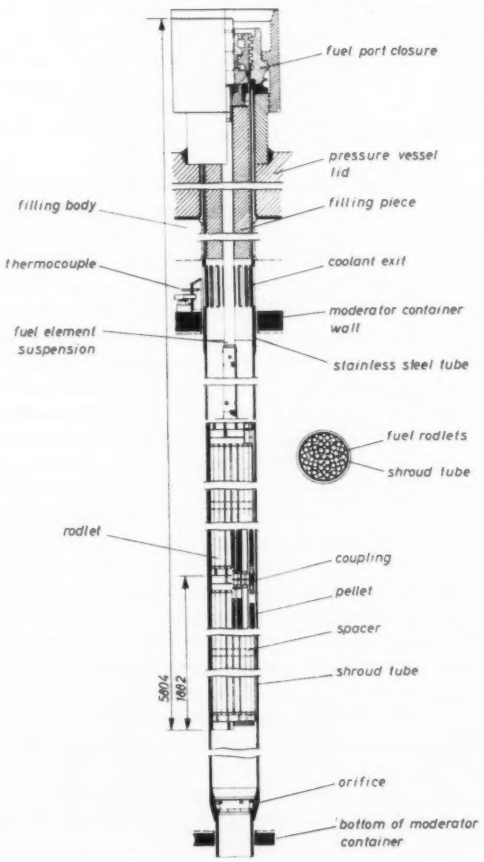
The heat produced is transferred from the reactor to the secondary system by means of two main coolant circuits, both consisting of a steam generator rated at 70 MW, a canned-rotor pump for a flow rate of 2325 m³/h at 7 atm pressure rise, and two hydraulically operated valves. The piping is kept extremely short. Either steam generator produces 152 tons of saturated steam per hour at 238°C and 33 atm, which is then fed to the turbine. Preheating of the feed water is done partly by means of bled steam and partly by the heat transferred in the two moderator heat exchangers, the primary side of which is fed with 4·5% of the main coolant flow rate. The inlet temperature of the D_2O pumped back into the moderator vessel may vary between 70° and 200°C according to whether the secondary feed water enters the first heat exchanger cold or already preheated to a higher temperature by bled steam. In this way the average moderator temperature can be adjusted to any desired value.

The steam generators are of the vertical U-type with D_2O inside the tubes. The heavy-water part below the plate has an unusual design. The space is subdivided by a separating sheet into an inlet and an outlet chamber. Instead of a manhole there is a big opening, allowing free access for repairs and closed normally by a seal-welded flange. This is domed towards the inside in order to save heavy water.

Since big temperature differences exist in the moderator heat exchangers between inlet and outlet, a vertical arrangement with straight tubes and plates on both sides has been chosen. Its upper plate is in fact the bottom of a suspended chamber, whose inlet tube connexion to the vessel wall is made elastic by bellows to compensate for thermal expansion. The main circulating pumps are vertical single-stage canned-rotor pumps, with spiral housing welded to the piping. For repairs only the motor housing, which is bolted down and seal-welded, has to be removed.

In the pressurizer, which has a volume of 15 m³, a number of vertical heater tubes is mounted to a large bottom flange. The heating rods, laid out for 800 kW, can be inserted into the tubes from the outside. During operation, the water level is controlled in such a way that the ordinary volume change due to moderator temperature variation is taken up by the pressurizer, while for fast suppression of overpressure transients a water spray system is installed. The pressurizer is able to maintain the system at a pressure of 90 ±2·5 atm.

Section through a fuel element (Fig. 2)



AUXILIARY CIRCUITS

The feed and bleed system, which compensates for all volume changes exceeding the capacity of the pressurizer, consists of a regenerative heat exchanger, a reducing valve, two coolers, a D_2O storage tank, and two high-pressure feed pumps. During operation, a steady flow of 4 m³/h is fed into the system, whereas the water flow bled off the system is regulated corresponding to the pressurizer water level. In a communicating circuit the water can be degassed and loaded again with fresh deuterium gas up to the normal concentration of 30 cm³/l, in order to reduce the concentration of radiolytic oxygen. The relatively small quantity of oxygen that is produced can be removed from the system, if necessary, together with the deuterium and burnt in a catalytic recombiner.

The dissolved and the solid corrosion and fission products are removed in ion exchange columns. For replacement and drying of the ion exchange beds additional arrangements are provided. The re-enrichment of the D_2O is carried out in two distillation columns. The capacity of the plant will allow 300 l H_2O per year to be removed from the system.

CONTROL SYSTEM

The total heat producing and transferring system has two independent degrees of freedom as far as its stationary behaviour is concerned, namely the power and the tempera-

ture level. The control system is such that the temperature level may be chosen freely, whereas the power has to be regulated in such a way that the average coolant temperature will be held constant.

REACTOR BUILDING

The reactor itself and the primary circuits—including the more important auxiliary circuits as far as they carry radioactivity or D_2O—are housed in a spherical steel containment of 30 m (98·4 ft) diameter. The lowest point of the sphere lies 7 m (23 ft) above ground, which is just sufficient for lifting the heavy components such as the reactor vessel and the heat exchangers through three big openings into the containment by means of the built-in rotary crane of 100-ton load capacity. No additional lifting device is required. The interior of the containment is subdivided into several rooms of varying degree of accessibility.

The reactor room houses the reactor and control rods, the loading and re-shuffling machines, and the fuel element lock, which leads down to the storage pit. If the reactor is shut down the reactor room is accessible for maintenance.

Adjacent to opposite sides of the reactor room there are two shielded heat exchanger rooms, which house the main primary circuits. Due to the very strong, short-lived N-16 activity they are not accessible during operation, and for a few hours after shut-down.

The quadrant between the two heat exchanger rooms on the side towards the turbine hall is available for the test loop equipment. At the other side of the reactor room is a room for auxiliary equipment, which, under normal conditions, is accessible for inspection and service. The space outside the heavily shielded rooms is subdivided in three floors. The main service floor, however, is situated above these rooms. At the level of the middle floor, a passage connects the containment to the turbine house, where the control room is located. The main steam ducts and the feed-water piping are arranged under the bridge, while the control and measuring cables are fixed at the left and the right sides respectively. Most of the power cables from the switch gear building are placed underground and introduced into the containment from below.

The concrete cylinder supporting the reactor building rests on a foundation 9 m (29·5 ft) under earth level. It houses the fuel element storage pit and the coolers for the intermediate cooling system.

TEST FACILITIES

A nuclear power plant of 50 MW cannot produce power at an economic price with the present state of technology. As a prerequisite many problems concerning the behaviour of fuel elements and coolants under operating conditions have to be solved. This reactor is particularly suited for testing purposes on account of its very high neutron flux density of 10^{14}n/cm^{2}s and its accessibility to the coolant channels. A frequent fuel element exchange, which might be necessary for testing, can be performed without difficulty, since the fuelling machine is designed for uninterrupted power operation.

Besides the possibility of using any coolant channel for water-cooled test elements of different design, there are six channels especially equipped for test loops. Depending on the nature of the coolant various facilities of different design are available.

There are two positions for experiments with water-cooled fuel elements, where the water enters the channels from the reactor manifold but leaves the reactor through a separate pipe and, after passing measuring and testing devices, returns to the main circuit. This loop will be of particular value for boiling experiments.

Two other positions are equipped for experiments with water-cooled or steam-cooled elements in a closed circuit having its own pump and heat exchanger but being connected to the main pressurizer and maintained at the same pressure. This kind of loop will be suitable for steam superheating experiments.

In order to be able to carry out loop experiments with various coolants at different pressures and temperatures and independent of the reactor coolant, a pressure tube is built into the testing channel.

Finally, one of the eighteen inclined tubes has been designed for irradiation of smaller material samples, which can be inserted and removed during operation by means of a rabbit contrivance.

CONCLUSIONS

Since the reactor is laid out on a fairly conventional basis many improvements may be expected after some years of experience. In particular the possibility of obtaining superheating without changing the reactor appreciably should prove of practical interest.

Once these superheating experiments are carried out successfully and its feasibility demonstrated satisfactorily in one or two loop experiments, all peripheral channels could be commissioned for superheating. This would on the one hand improve the net efficiency of the whole plant and on the other ease the work of the already installed steam generators so that the total output is again augmented. It is believed that this reactor concept will appear attractive not only in Germany, but in other countries with an industrial background sufficient to support their own power reactor development.

Finally, it might be mentioned that the long-term goal of the development of the pressure-vessel type D_2O reactor should be the thermal heterogeneous Th-breeder. It has been calculated that a breeding ratio greater than one is feasible.

Such a reactor would be able to work with a fuel cycle requiring only natural Th for fresh fuel, but there would not be any appreciable surplus of fissile material or, generally speaking, the doubling time would be almost infinite. Therefore, in every new reactor of this type the Th/U-233-cycle would have to be started by an initial U-235 enrichment. But even if the required initial investment is added to the capital charges, the economic picture does not appear unattractive, as the markedly reduced fuel costs, which result from the high and only metallurgically limited burnup, will more than balance the increase in capital costs. In view of the relatively high fuel power rating, which is not very different from that of light water reactors, the considerable fuel investment would appear to be justified.

The project has both long-term and short-term goals. On the one hand the 50 MW pressure-vessel reactor, to be constructed in the near future, will prove its value both as a power and as a test reactor by demonstrating the suitability of this type for power production, and by contributing decisively to the further development of power reactors. On the other hand it is hoped that the pressure-vessel reactor in its finar shape, in particular as a Th-breeder, will bring about powe production at competitive prices.

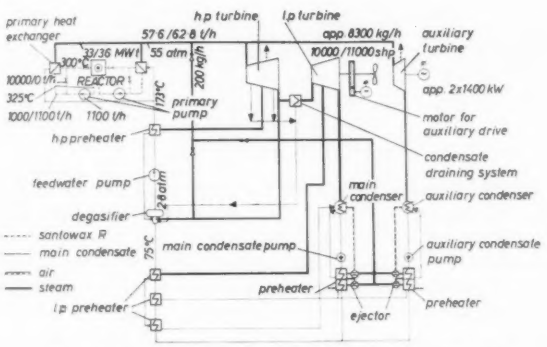
ATOMIC ENERGY
IN THE GERMAN
FEDERAL REPUBLIC

Safety and flexibility, rather than low cost are the keynotes of this OMR design

The Interatom marine reactor design

by Dr F. E. FARIS, Interatom, Internationale Atomreaktorbau GmbH

A VERY CONSERVATIVE APPROACH to the design has been adopted and it is believed that operation of a research ship would demonstrate the feasibility of relaxing many of the requirements in the case of future plants, with resultant cost saving. The design of the secondary shielding, for example, has been based upon the assumption that 10% of the fission products from the primary system enter the containment shell, even though with the carefully designed cooling and safety systems it is not considered credible that an accident could result in such a release with the ship still afloat. All components and supports have been designed to withstand a vertical acceleration of 1·2 *g* and a horizontal acceleration of 1 *g*. The control-safety rods and the fuel elements will be tested at these accelerations and higher as part of the experimental programme. The recommendation of the 'Conference on the Safety of Life at Sea' held in London last year have been observed throughout, and close contact with German Lloyd is being maintained.



Flow diagram for the main heat transfer system (Fig. 1)

The flow diagram for the main heat transfer system, which consists of two loops, is given in Fig. 1. The thermal rating of the reactor for normal operation is 33 MW with a maximum power level of 36 MW, resulting in 10,000/11,000 shp for propulsion plus power for the auxiliary loads aboard ship. To provide the flexibility desirable for a research ship, the heat transfer system is designed so that the power could be increased about 10% merely by the addition of larger pump motors. Also it is expected that measurements of the power distribution and control rod effects in the core of the operating reactor would permit thermal power levels about twice as great in the case of future plants without major changes in the core design.

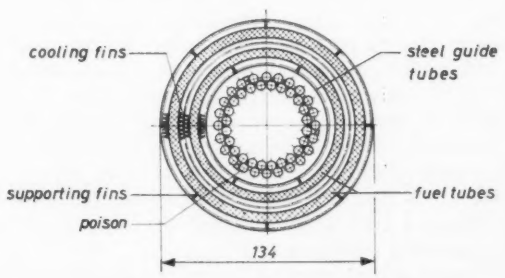
For normal operation at 33 MW the coolant, a mixture of terphenyls, enters the reactor at 300°C and leaves at 325°C. The system is operated with constant coolant flow of 2200 tons/h constant reactor-outlet temperature, and a constant steam pressure of 55 atm; and load changes are accomplished by varying the reactor-inlet temperature with a bypass around the steam generators. Saturated steam at 55 atm, chosen on the basis of calculation by Kernenergie indicating a maximum efficiency for this condition, passes from the two steam generators to a common header.

The piping in the main primary heat-transfer loops, which has a nominal diameter of 30 cm (11·8 in), has been provided with compensators in order to achieve compactness. The coolant in each main primary loop is circulated by a pump with a power of 135 kW through a vertical heat exchanger containing 16 mm (0·63 in) dia. U-tubes. A blocking valve, which can be closed quickly either by a pneumatic or an electric drive in the case of an emergency, is located at the reactor-inlet and the reactor-outlet of each of the loops. Appropriate safety valves are also provided.

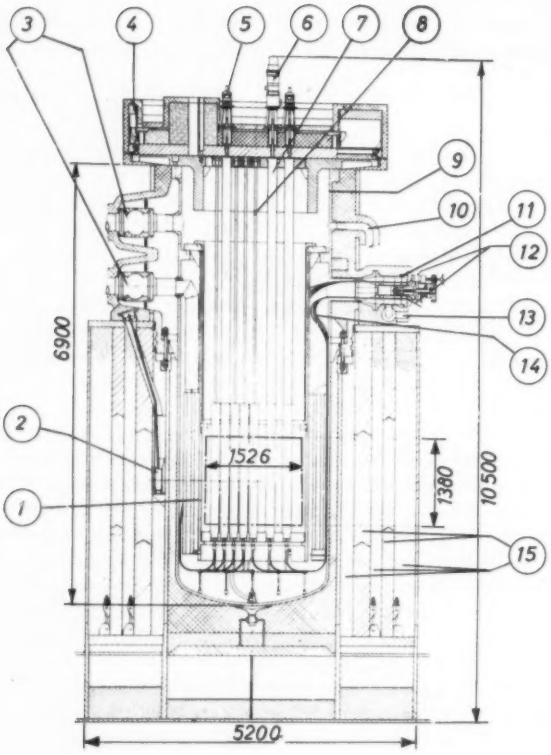
Two auxiliary cooling systems are provided for the removal of afterglow heat in case neither main heat-transfer loop is operating. The heat is normally transferred to air blown through the heat exchangers. In the case of an extreme emergency, e.g., sinking of the ship, the heat exchangers are flooded; and heat can be removed by natural convection for angles of list less than 110°.

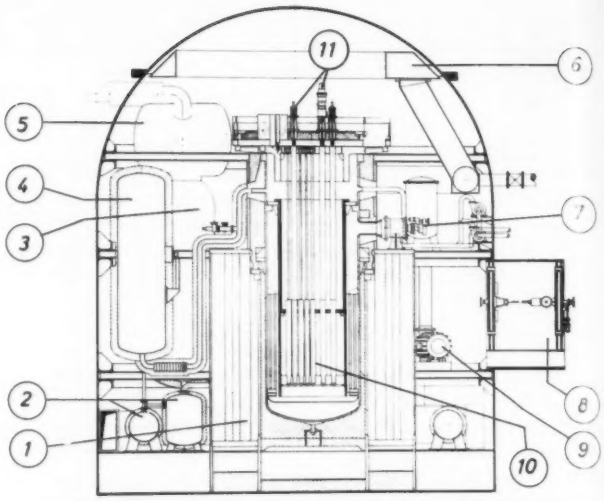
An additional coolant process system is provided to maintain pressure and to remove impurities, the gases (about 0·22 Nm^3/h) and the polymer (about 13·5 kg/h, 29·8 lb/h) formed as a result of radiolysis and water which may enter because of leaks in the steam generator.

The reactor contains 7·2 tonnes of the alloy U–3·5% Mo–0·1% Al in the form of elements containing two



Cross-section of the fuel element (Fig. 2)





1 biological shielding; 2 drain tank; 3 primary loop heat exchanger; 4 surge tank; 5 steam drum; 6 ventilating system; 7 sampling valve; 8 air lock; 9 primary pump; 10 core; 11 control and shim rod drive

(Above) Arrangement within the containment shell (Fig. 4)

1 core tank; 2 ionization chamber; 3 auxiliary cooling system; 4 rotating shield; 5 shim rod; 6 control rod drive; 7 control rod; 8 fuel element drive; 9 reactor tank; 10 inlet coolant purification; 11 sampling valve; 12 thermocouples; 13 outlet coolant purification; 14 tubes for coolant samples and thermocouples; 15 biological shielding

(Left) Vertical section of the reactor and the primary shielding (Fig. 3)

concentric tubes clad with the alloy A1Mg 3. The uranium is enriched 1·88%. The fuel elements have been designed so that with conservative assumptions regarding swelling, an average burn-up of at least 3000 MWd/t can be achieved. In view of encouraging results on similar alloys tested recently in the USA and in France, it is hoped that experience will demonstrate an appreciably higher upper limit. A structure extending from each active fuel section to the reactor cover is provided for support in the case of vertical acceleration, and some of the cooling fins of the concentric fuel tubes contact the stainless-steel coolant-channel walls to provide support in the case of horizontal acceleration. A cross-section through a fuel element is shown in Fig. 2.

Nineteen of the fuel elements are designed to contain control-safety rods within the inner stainless-steel coolant tube. The absorbing sections (boron carbide in an annular array of stainless steel tubes) will remain in the core even if the ship sinks upside down. The reactivity worth of all 19 absorber sections is about 14%. In comparison, the excess reactivity of the cold-clean core is of the order of 10·7%.

A cross section through the reactor and the primary shielding is shown in Fig. 3. The reactor tank has an inner diameter of 2·32 m (7·61 ft) and a wall thickness of 4 cm (1·56 in). The cover is designed so that it can be lifted and rotated for fuel handling with no contact between the inside of the reactor tank and the external atmosphere. The primary shield consists of annular regions of water and steel in a tank with an outer diameter of 5·2 m (17·1 ft). With the reactor in operation, the dose rate at the surface of the shield tank has a maximum value of 76 mrem/h, with the main contribution from secondary gamma rays.

The entire primary system is located in a containment shell with an inner diameter of 10 m as shown in Fig. 4. The shell is designed to withstand an inner pressure of 5 atm (gauge) at a maximum temperature of 190°C. These conditions, which are the worst resulting from any accident, are based upon a rupture in a steam line. The shell is designed so that it can withstand the external pressure of water if the ship sinks up to a depth (midpoint of shell) of 35 m (114·8 ft). Below this depth, valves open to flood the container and then close when the pressure difference has been reduced sufficiently. An airlock for entry of personnel is provided, since repairs, if necessary, can be carried out with the reactor in operation. The entire shell is provided with secondary shielding consisting of a 35·5-cm (14 in) thickness of concrete up to the removable cover, which is shielded by 7·6-cm (6·9 in) of lead.

The containment shell is located within a gas-tight reactor compartment having a length of 17 m (55·8 ft), a width of 12 m (39·4 ft) and a height of about 14 m (45·9 ft). The reactor service systems (e.g., coolant purification and degassification system) are in the forward section of the compartment. Appropriate secondary shielding is provided so that the dose rate outside of the reactor compartment in access areas nowhere exceeds 0·6 mrem/h, even if the reactor is in operation with defective fuel elements (about 700 cm² (108·5 in²) of uranium surface exposed to the coolant).

Acknowledgments

The author wishes to thank the managers of Kernenergie, Dr von zur Mühlen and Mr Schmerenbeck, for their support of the programme, their many suggestions and permission to use information relating to the ship and the conventional portion of the plant. Thanks are also due to Professor Weinblum of the University of Hamburg for his valuable suggestions relating to ship design and conditions to be expected under operation, to Directors Heimberg and Torner of German Lloyd for their interest in the programme and willingness to make information available and to Mr Hildrew of British Lloyd for discussions relating to the requirements for nuclear-powered ships in the UK. The author also wishes to thank the members of the technical departments of Interatom and Kernenergie, whose ingenuity and untiring efforts have brought the design to its present stage.

ATOMIC ENERGY IN THE GERMAN FEDERAL REPUBLIC

Stringent provisions provide protection against radiation while avoiding unnecessary restrictions

THE LEGAL POSITION

By Regierungsrat Dr W. BORST,
Federal Ministry of Nuclear Energy and Water Economy

GERMANY'S ATOMIC Energy Act came into force on January 1, 1960. This provides broad covering legislation, either in itself, or by enabling the Government or the Atomics Minister to promulgate complementary regulations. It lays down responsibility for nuclear damage and provides for fines or other penalties for the misuse of nuclear energy or activities which infringe laws or official decrees in this field. It also embodies or enables rules to be made for the strictest control of nuclear installations, nuclear fuels and radioactive materials as well as detailed rulings on radiation protection.

Nuclear installations

The term 'nuclear installations' is taken to cover all facilities for the production or the fissioning of nuclear fuels, as well as the reproeessing of irradiated nuclear fuels. It also covers propulsion reactors and installations for the production of uranium of nuclear purity; but it excludes installations for processing enriched uranium or for storing nuclear fuels.

The Act makes a special licence mandatory for the construction of nuclear installations, for their operation, for substantial alterations to them and for any other form of ownership. Such a licence may be obtained by any reliable person whose employers are reliable and have the requisite expert knowledge. It is in no way reserved for the State, companies under State control, or legal entities.

On the other hand, licences may only be granted when a series of material conditions are complied with. In particular, the siting of the installation must not conflict with any overriding public interest, while the most advanced techniques and thinking must be used to prevent the installation causing any harm. Furthermore, adequate provision must be made for eventual compensation for damage caused by incidents at the installation.

The licensing system is described in detail in the Ordinance concerning the Procedure for Licensing Nuclear Installations. As in the United States, a safety report must be submitted for each nuclear installation. The report must describe all hazards connected with the plant and the safety measures devised to counter them. If a construction licence only is granted, provisional data on plant operation must still be submitted so that the licensing authorities can have a general picture of the plant and its operation. The authorizing department calls in experts, informs all interested authorities, places the project on open record and makes available to the public the request for a permit, the plans and the safety report.

Objections to the project are presented at public hearings. This would normally concern objections from inhabitants of the surrounding area but anyone can take part in the hearings. The authorizing department must also consider whether all the other licences which must be made available before a plant can go into operation can, in fact, be granted; for example, a special permit for disposal of contaminated effluents.

Decisions on the overall licence foreseen in the Act and on the other licences are taken by the State authorities. No new authority and no Federal atomic administration has been set up. Nethertheless, the Federal Atomics Minister can instruct both the licensing and the supervisory authorities on the basis of advice made available by the Reactor Safety Commission and other experts. Supervision of the installations is continuous. The supervisory authority pays special attention to see that licence conditions and restrictions are respected. In cases of serious failure to observe such conditions, plant operation can be suspended and the licence withdrawn without any right to compensation by the holder.

Radioactive materials

The Act also makes a licence mandatory for anyone who, outside a nuclear installation, engages in the transport, storage, processing, treatment or the use, in any manner, of nuclear fuels and also for importers and exporters of such materials. The First Radiation Protection Ordinance extended this licensing requirement, *mutatis mutandis*, to all other radioactive materials. It also added the regulation that the acquisition or transfer of radioactive materials, including nuclear fuels, must be notified to the supervisory authority.

The conditions under which the licence in this case may be granted or must be granted—the applicant generally has a legal claim to the licence—are similar to those for a nuclear installation. However, no formal licensing procedure is provided. Transport and storage of nuclear fuels, import and export of nuclear fuels and radioactive materials are licenced by the Federal authorities. Other licences in this particular instance are granted by the State authorities on the instructions of the Atomics Ministry.

Radiation protection

The main part of the First Radiation Protection Ordinance is a series of general protective provisions which apply equally to nuclear installations, nuclear fuels and other radioactive materials. These are in line with Euratom recommendations on health and safety, and recommendations of the International Commission on Radiological Protection and can be compared with part 20 of the AEC regulations.

They are designed primarily to ensure that radiation doses received by employees and the general public as well as the dissemination of radioactivity are kept as low as possible. They also lay down maximum occupational radiation doses, maximum tolerance levels for radioactive materials in air and water, provide that workers in this field must have medical checks and that certain types of incident must be reported.

ATOMIC ENERGY
IN THE GERMAN
FEDERAL REPUBLIC

Both adequate, guaranteed compensation and cover are ensured

LIABILITY AND INSURANCE

by Hans Hilger HAUNSCHILD
Federal Ministry of Nuclear Energy and Water Economy

PROVISIONS DEFINING liability for nuclear damage are given special prominence in the German Atomic Energy Act. These were enacted with two main considerations in view: (1) far-reaching compensation for the victims must be guaranteed; (2) atomic research and industry must not be hampered by unlimited liability and the difficulty, or impossibility, of obtaining cover.

To attain these partially contradictory objectives, the authorities have decided to intervene on a large scale. The German Atomic Energy Act is characterized by this State aid.

Liability

The Act's provisions concerning material liability form special legislation which transcends general ordinances on liability and, in particular, those of the Civil Code on unlawful acts and on the law of neighbourhood, leaving them basically unaltered. (Liability under the Act is an absolute liability which takes no account of blame. This applies fully to nuclear installations. It also applies to the possession of nuclear fuels and radioactive materials, with the proviso that there is no case for compensation where the damage was caused by an incident which the owner could not have avoided, even though he had taken all the precautions imposed by the circumstances, and which was not due either to an inadequacy in the protective installations or to a breakdown in their operation).

Grounds for exoneration are not recognized by the Act. Liability also comes into play when the damage has been caused by *force majeure*, e.g. through some natural catastrophe or even through acts of war.

Absolute responsibility falls on the owner of the nuclear installation. In contrast with some foreign laws, the Act does not recognize the so-called 'channelling' of liability according to which no one apart from the owner is liable. German law maintains the liability of other persons—in particular sub-contractors, architects, builders, workmen etc. The position of these persons is less advantageous only on the legal side by comparison with other legislation. Their financial position is identical. This is because the Act prescribes that the above-mentioned persons are to be included in the financial cover the owner must obtain.

Claims

The time limit for claims for compensation in cases of nuclear damage has been fixed at 30 years. Difficulties which may arise in finding cover for this period, which is long by comparison with those laid down in foreign laws, will be overcome by State aid.

Liability is limited to damage to persons and property. Compensation for immaterial damage is not provided. With damage to property, the actual value of the object in question plus the cost of insuring against any possible danger resulting from radiation emitted by it, must be restituted. If as a result of personal injury a pension has to be paid, this must not exceed DM 15,000 (£1250) per year.

Apart from these stipulations, the Act also fixes an upper limit to the liability risk in so far as a nuclear plant is involved—liability ends with cover of DM 500 million (£41 million). This upper limit is also valid for liability under other sections of the Civil Code—e.g. unlawful acts. An exception to this limitation is where the person in question—or if it is a corporate body its legal representative—deliberately caused the damage. For the less stringent liability involved in the possession of radioactive materials, outside nuclear installations, there is no limit on amounts of compensation.

Cover for nuclear risks

The Act requires all persons whose activities can lead to nuclear incidents to take out adequate cover. It makes clear that in every case where an official licence is needed there is also an obligation to take cover for liability. This is valid in the first instance for nuclear installations and also for all other ways of handling of radioactive materials which are subjected to licensing as a result of the Radiation Protection Ordinance.

The type of cover, its extent and amount for nuclear installations is fixed by the appropriate authorities during the licensing procedure, taking into account the particular circumstances of each individual case. Major considerations are the possible danger from the plant, the total available cover and the possibility of paying for the corresponding premiums.

Federal obligation

In contrast with British law, the Act does not lay down a fixed sum, valid for all plants, to be provided by private cover. This procedure could be chosen because Federal liability adds to and completes private cover without any hiatus. This goes up to the maximum liability, as previously mentioned, of DM 500 million. This sum comprises private cover as well. The Federal Government's obligation to indemnify comes into being automatically for all authorized nuclear installations, without the need to conclude any special agreement. As with private cover, the State's protection takes in not only the owner of the nuclear installation but also the other persons whose connection with the installation could impose a liability on them. In cases where damage has been caused deliberately by a private person or the legal representation of a corporate body, the State has the right of recourse against the private person or the corporate body. The State indemnification period is limited to ten years. But installations which are authorized before it expires on December 31, 1970 will continue to be covered.

ATOMIC ENERGY
IN THE GERMAN
FEDERAL REPUBLIC

Lack of state aid for construction has held back building of nuclear power stations

FINANCING ATOMIC ENERGY

by SIDNEY HOLLANDS B.Com.,
News Editor, Nuclear Power

EVEN A cursory look at the German nuclear power programme will show that in 1961, few projects under the country's 500 MW programme are near realization. This programme initially provided for the construction by 1965 of five prototype nuclear power stations with an output of some 100 MW each. However, development work under this 1957 (Eltville) programme is only to be completed in the next 12 months, according to the latest annual report by the German Atomics Ministry.

There are a number of political and organizational reasons for the comparatively slow progress towards the 1965 target such as the late entry (1955) into the nuclear field at a time when other countries had embarked on an industrial nuclear programme. But underlying them all is the problem of finance—by the Government, semi-public interests and by industry.

State aid

The Government's economic policy is to allow private capital the greatest possible freedom and this extends to the building and operating of nuclear power stations. The result is that there is no state financing for the construction of nuclear power stations and consequently no national nuclear power programme such as in Britain and France.

State aid, in the main, is limited to guaranteeing investors against loss. The Government, for instance, has agreed to bear a specified proportion of the losses incurred in operating nuclear power plants so as to reduce the expense to private owners. This forms the major development contribution by the Government and is conditional upon the operator agreeing that the arrangement covers the life of the plant and that should there be any operating profit, some or all of the Government's contribution should be repaid.

Other government aid comes in the form of defraying 30%–50% of the development cost of work on agreed power reactor design studies and projects and on marine reactor research; guarantees are also given by the State on repayable loans at the start of development work. Aid is also given to research establishments.

From 1956 to 1960, a total of DM 764·3 million (£62 million) was set aside or actually contributed for nuclear research or nuclear industrial undertakings in West Germany by Federal and state authorities. This has led to a comprehensive development and research programme but lack of adequate financing for the actual construction of nuclear power stations has held back development.

Public utilities

There is no central authority responsible for organizing power supplies in the Federal Republic and current is fed to the grid by nine large supply undertakings which produce much of the electricity themselves. Ownership is mixed with the Federal Government, Land governments and private interests holding a stake in the companies. Each undertaking is run on business lines and is free to decide its own investment policy.

There is little difficulty in obtaining funds for the building and operating of research or experimental reactors as these usually come from public monies with some aid from private industry. But faced with the knowledge that there is no State aid for the construction of nuclear power stations and also with a statutory obligation to provide the maximum amount of power at the lowest possible cost, the public utilities are placed in an unenviable position. On present estimates, any large nuclear station built now will involve costs much higher than for a conventional station, a consequent falling off in profits and a possible accounting to shareholders for the decision to go in for an uneconomic proposition.

One way to limit risks would be to set up subsidiary companies in the form of limited liability or joint stock companies which would own some 30% of the capital. The remainder could be raised on the capital market. However, this is complicated by the fact that much of the capital would not be needed for some time during which period interest rates and availability of money could have changed.

Generally, the utilities have adopted a waiting game and have contented themselves with placing contracts for design studies. One example is the Gesellschaft für die Entwicklung der Atomkraft in Bayern mbH, Munich, a limited liability company formed by four electricity undertakings, a chemical firm and the Land of Bavaria. This group has placed a contract with Siemens Schukert-Werke AG for the design of a 100 MW D_2O reactor at a fixed price of seven million DM. Two-thirds of this sum will be provided by the Federal Government.

Faced with the possibility that under the present financing arrangements, a large power station is not likely to be built in the near future—apart possibly from the AKS OMR project under the Euratom programme (the company has now changed its name)—there has been pressure put on the Government to lay down a clear and decisive financial policy.

There are indications that this pressure is beginning to have some effect. The Government has tried, within the framework of present legislation, to press forward with a nuclear-powered ship and is endeavouring to put this programme in operation as a development project. In addition, some indication has been given that Federal aid may be forthcoming for the construction of stations by the mention both in the presentation of the 1961 budget and the present annual report that as design and construction are expensive and uneconomic, the Government should partly finance this work.

ATOMIC ENERGY IN THE GERMAN FEDERAL REPUBLIC

REACTOR DEVELOPMENT

by J. SPENCER BURKETT, FLA
Assistant Editor, Nuclear Power

SLOW PROGRESS has been made towards implementing West Germany's 500 MW programme announced in 1957. Apart from the Kahl and AVR plants, there are, in the design stage and with State subsidy, a 150 MW BWR, and a 150 MW AGR, both under two-year contracts from the power utility SKW with completion by the summer. Also, there is a 100 MW heavy water design, due for completion by 1962.

Under negotiation for State subsidy, with the likelihood of agreement within a few months, are three further designs: a 15 MW high temperature gas-cooled reactor, with direct cycle, based on the AVR reactor already under construction; a 150 MW organic moderated reactor that Interatom hopes to complete within the year, and, if proven satisfactory to the utility, will participate in the second round of the US/Euratom programme for completion by 1965; and a 50 MW heavy water multi-purpose reactor.

Small reactor concepts that have been prepared recently by industry at the suggestion of the Ministry, and are in the proposal stage only, include AEG's 25 MW boiling water reactor and a Deutsche Babcox and Wilcox design for a 15 MW advanced gas-cooled reactor. There is also provision for a 5 MW PWR plant.

The Hamburg company GKSS, recently called for tenders from eleven ship-building companies for the construction of a ship—whether it is to be a tanker, ore carrier or passenger vessel is a choice left to the builders. The power, however, has been fixed at 10,000 shp and the major requirement is that the reactor component and link-up must be so designed that the reactor, under test—OMR, PWR, BWR or GCR—can be easily removed and replaced. GKSS, at Geesthacht, are thinking along the lines of a 22,000 dwt vessel, 580 ft. in length, 80 ft. wide and 32 ft. deep, that could be completed by 1965 and would cost, on the basis of current prices and wages, around £M3. Proposals had to be completed by the end of January.

The Ministry for Atomic Energy is therefore currently sponsoring five ship design studies, three of which have been approved for a subsidy, the other two are in the course of negotiation (see Table). The Interatom OMR design study, which commenced in 1959, is well advanced, and with the additional incentive of Euratom support, it is claimed that building could start at the end of the year.

The other two Government subsidized design studies, a PWR by Siemens-Schuckertwerke and a BWR by AEG, were started in 1960 and will only have reached the preliminary design stage by the end of this year. Both companies have licensing agreements with American firms, SSW with Westinghouse and AEG with General Electric. Deutsche Babcock & Wilcox who recently started work in conjunction with the Blohm and Voss shipyard for the design of a gas-cooled reactor, of a type intermediate between the British AGR and the DRAGON project, are still waiting for ratification of Government financial aid. BBC/Krupp are negotiating with the shipyard AG Weser and the Government for the design of a high temperature gas-cooled reactor similar to the DRAGON type.

POWER REACTOR DEVELOPMENT

TYPE	OUTPUT (MWe) (or shp for ships)	STATUS	DESIGNER* (and/or Contractor)	CUSTOMER*	COST (and man-hours)	COMMENTS (Fuel (enrichment), cladding, coolant, exit temp. (°C), etc.)
BWR—Kahl	15	critical Dec. '60	GE/AEG	RWE	Total (without fuel): DM.M35 (£M2·9) (RWE-DM.M28)	UO_2 (2·6%), Zr-2; 286, steam 258°C
BWR	25	proposal	AEG	—		UO_2 (slightly), ss; steam 620°C; nuclear superheat, direct cycle
BWR	150	design study Apr. '59-mid '61	AEG	SKW	Total:DM.M9·6 (£M0·8) (AEG-M2; SKW-M3·6; Gvt.-M4)	UO_2 (1·8%), ss; (includes 50MW nuclear superheat)
BWR	240	proposal	GE/AEG	RWE		two-stage with nuclear superheat
BWR (Ship project)	20,000	design study '60-'61	AEG	DW	Total: DM.M3 (£M0·25) (Gvt.-M1·5)	UO_2 (2·6%), Zr-2; direct cycle
PWR	5	provisional	MAN			two-stage reactor; graphite, D_2O separate zones
PWR (Ship project)	20,000	design study Jan. '60-Jan. '62	SSW	HWH	Total; DM.M3 (£M0·25) (Gvt.-M1·5)	UO_2 (5%)
Magnox		proposal	(UK)GE/MAN	RWE		
Magnox	300	proposal	EE/DBW	RWE		
AGR	150	design study Apr. '59-mid '61	DBW	SKW	Total: DM.M9·85 (£M0·82) (DBW-M3·85; SKW-M2; Gvt.-M4)	UO_2 (2%), ss; CO_2, 50 atmos, 485
AGR	10-15	proposal	DBW	—	development: DM.M25 (£M2) construction: DM.M25	UO_2 (slight), ss; CO_2 or He, 500; to study compatibility of fuel elements
AGR (Ship project)	20,000	design study	MAN	BV	200 man-months on stage I	cross-flow, ss
GCGM (Ship project)	20,000	project	DBW	B&V	DM.M3 (£M0·25) (Gvt.-M1·5) to be ratified	CO_2 or He
HTGR-Julich	15	cons. started late '60 critical '63	BBC/Krupp	AVR	DM.M40 (£M3·3) AVR-M20; Gvt.-M20)	UC (20%), ThC, graphite balls; He or He-Ne, 850; steam (superheated): 505°C
HTGR	15	design and development	BBC/Krupp	AVR	DM.M50 (£M4·2) negotiations with Government	UC (20%), pebble bed; N_2, direct cycle closed circuit gas turbine
HTGR (Ship project)	10,000	project	BBC/Krupp	AGW	negotiating	UC (20%), ThC; pebble bed; gas turbine
OMR (Mosbach)	150	design study	AI/Interatom/ BBC	KBWP	est. design: DM.M3·4 (Gvt 50%) est. construction: DM. M200 (£M16·6) contract being negotiated est. man-hours '61: 13,000	If accepted, KBWP to decide on construction as part of Euratom programme with completion by '65
OMR (Ship project)	10,000	design study '59-'61	Interatom	GKSS	'59-'61: DM.M7·5 (£M0·62) Shared by Gvt., four N.German coastal states and Euratom man-hours: '59-'60: 205,000 '61: 100,000	new contract linking Euratom signed Jan. '61
D_2O-MZFR	50	design study	SSW		Total: incl. site, interest, etc., excl. development – DM.M132 (£M11) still negotiating	multi-purpose research reactor
D_2O	100	design study Mar. '59-'62	SSW	GEAB	Total: DM.M14·56 (£M1·2) (SSW-M7·56; AB-M2·333; Gvt.-M4·667)	CO_2, pressure tube
Zirconium hydride	10	proposal	Interatom	—		UC (enriched), Na, steam at 550°C; long-term research

* For full names of companies see: 'Guide to German industry', p. 86

ATOMIC ENERGY IN THE GERMAN FEDERAL REPUBLIC

The aim is to catch up with other countries as quickly as possible

Fuel elements for German Reactors

by Dr M. BECKER, Nuklear-Chemie und Metallurgie

FUEL AND ELEMENT DEVELOPMENT in the Federal Republic must in the first instance be tailored to meet the needs of the reactors already in operation and those which, it is expected, will be built. Although this represents in part work to catch up with overseas development which has already been carried through to fruition, it is not significant. German industry wants to qualify as a producer of fuel and fuel elements with emphasis on developing more economic fabrication methods for current types and also development of new simple elements which will thus be economic to produce.

NATURAL URANIUM

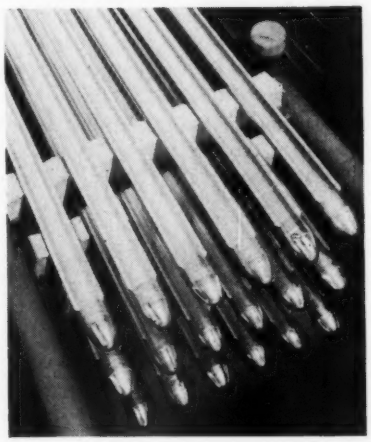
The FR2 research reactor and the Siemens Multi-purpose Reactor which has a high output for a research unit of 200 MWt, as well as the SNDR-2 power reactor, are heavy water moderated natural uranium reactors (details of power reactors are given in the table on p. 80 and of research reactors in the table on p. 61). Fuel for these can be produced at home, although not on an economic basis. The uranium ore, mined in the Ellweiler area of the State of Rhineland-Palatinate, is processed in an experimental unit near the mine. The concentrate goes to the only uranium production plant in Germany at Wolfgang near Hanau/Main. At present most of the concentrate processed at Wolfgang is imported.

The plant can produce 40 tons of metal annually. The processing techniques for the production of nuclear pure, sinterable UO_2, or of uranium metal, have been developed since 1955 and are continually being improved.

At present, the uranium is purified by a well-known solvent extraction process. The resulting water solution of uranyl nitrate is treated with an ammonia/air mixture under strictly controlled conditions to form ammonium diuranate (ADU) as a coarse precipitate with good filtering properties. This step is of major importance because on it depend to a large extent the sintering properties of the uranium dioxide produced at a later stage. After drying at 100°C the ADU has the following composition: 91-92% UO_3; 2·1-2·4% NH_3; 5-7% H_2O.

The filtered and washed ADU is calcined and reduced with hydrogen to UO_2 in cylindrical rotary furnaces to give a very uniform product. Sintering properties of the UO_2, apart from the above-mentioned precipitation, are also sharply affected by the time and temperature factors in the calcination and reduction stages. Normal ceramic grade UO_2 has a surface area of 2–3 m²/g. It should be mentioned that in the furnace stage, changes in the calcining and reduction process conditions will produce powders of considerably higher surface areas.

For the production of UF_4, oxide with somewhat different properties from ceramic grade is made. The reaction between the UO_2 and anhydrous hydrofluoric acid at high temperature also takes place in a cylindrical rotary furnace. Metal is produced in 45-kg (100-lb) billets per charge by reacting the

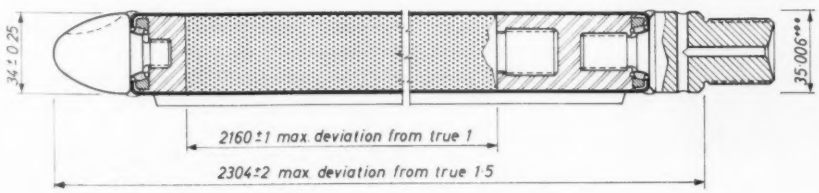


Trial elements for the FR2-Karlsruhe (Fig. 1)

UF_4 with calcium. The company has succeeded in obtaining a clear separation between metal and slag with a resulting high yield and thus no necessity to treat residues with acid. Uranium metal is the second end-product of the plant and is being made into fuel elements for the FR2 reactor.

Natural uranium rods

The development of fuel elements for the FR2-Karlsruhe



Section of the fuel rod for the FR2-Karlsruhe (Fig. 2)

reactor was completed during 1958. Up to the beginning of 1960 some 10 tonnes of elements were made, corresponding roughly to two core loadings. Figure 1 shows a number of such elements. The major production phases and the development work are as follows.

Melting—The unworked uranium billet from the UF_4/Ca process, weighing about 100 lb, is melted in a graphite crucible coated with magnesium zirconate and thorium oxide, together with uranium metal chips, in a high vacuum induction furnace. Alloying with 0·3/0·4 w/o of niobium, desirable because it results in fine grain formation, presented certain difficulties and the addition of niobium is done at the reduction stage in the form of the pentoxide. This co-reduction process has proved successful. The molten metal is held for about 20 min at a temperature of 1250°C. This allows gas inclusions to escape and the remaining slag to float to the surface. The molten uranium is then allowed to pour through a hole in the bottom of the crucible into a mould made of similarly-coated graphite heated at the top. The ingot is trimmed and tested for voids by ultrasonic probes.

Extrusion—The ingot, which has a diameter of about 110 mm (4·33 in) is immersed in a salt bath and raised to a temperature of 950°C. Meanwhile, the container and die for the ingot are heated to 630°C in an air circulating furnace and then placed in a 100-ton press. The hot uranium metal, its surface protected by the adherent salt is extruded into a rod about 2·5 m (8·2 ft) long and 34 mm (1·30 in) in diameter. The salt acts as a lubricant and protects the surface of the rod from oxidation. Uranium is easily extruded in the gamma-phase and it was possible to perfect the process without special extrusion presses. A considerable amount of research, however, had to be done with various dies. Best results were obtained with a Stellite matrix.

Heat-treatment—To obtain fine grain and prevent work-orientation, the rods, now in three sections are water quenched after heating to 950°C in a salt bath. The rods are then straightened and alpha-annealed in a vacuum furnace. The decisive effects of the heat-treatment of uranium metal on its behaviour under stresses caused by temperature changes and reactor conditions necessitated a careful development in this area (thermal cycling; type and amount of alloying material; texture; grain size; ultrasonic testing; reactor tests etc.).

Final forming—The rods are turned to final dimensions (32 mm (1·26 in) dia.); hole and peg connexions are also turned together with a threaded section.

Vapour coating—After electro-polishing, the rods are successively coated with 0·01 mm (0·004 in) of zinc and then tin by a vapour-deposition process under high vacuum. The development of a special, economic vaporizing apparatus was required.

Canning—In an aluminium tube cleaned by conventional methods and closed at one end, three rod sections are inserted. The tube is evacuated and the hole and peg connexions made. The tube is then drawn through a matrix where it is provided with fins and shrinks slightly so that its inner surface comes into close contact with the tin on the surface of the uranium. Before closure, the tube is filled with helium and then the end cap is welded on by the argon-arc method. The weld is then inspected for leaks with a helium mass spectrometer. The design of the tube ends can be seen in Fig. 2.

Welding—Fuel material and canning are joined together by heating the element to 380°C in an autoclave at a pressure of 200 atm. The metallic bond obtained in this way between the uranium and the can has the advantage that it gives better heat transfer and better corrosion resistance where the canning is defective. Here again much preparatory experimental work was needed, especially in connexion with the choice of the best bonding materials and the conditions necessary for obtaining optimum bonding.

Surface treatment—After the bonding has been tested by ultrasonic apparatus, the surface of the can is given final treatment which includes etching with alkali and acid baths using ultrasonics to obtain maximum effect, polishing and surface consolidation.

Sintering line for UO_2 pellets (Fig. 3)

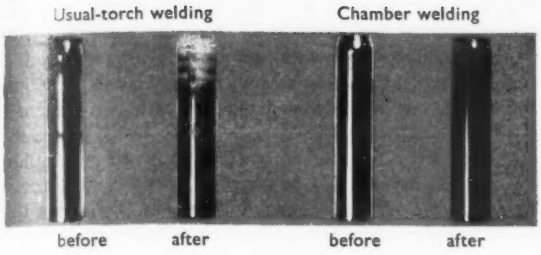
Natural uranium tubes

The proposed increase in the power of FR2 has necessitated a new fuel element concept. For this it is intended to use uranium metal tubes with an outside diameter of 32 mm (1·26 in) and a wall thickness of 7 mm (0·276 in), protected internally and externally by aluminium tubes to which they are bonded. Technological development of these elements is in progress and the main problems are the testing of the various ways of making the hollow uranium elements and the production of the internal canning.

Casting—The object of these tests is the completion of a large number of tubes by casting processes within the closest possible tolerances to cut down subsequent working to a minimum. The major problem is to remove the material without damaging it for further processing.

α-phase extrusion—Structure is finer-grained as a result of the considerable deformation, while tolerances can be more closely held than in casting and better surface conditions can be expected. A disadvantage is the grain orientation.

γ-phase extrusion—The considerably higher temperature compared with that in the preceeding process makes far greater demands on the wear-resistance of the dies etc. Tests are being made with molybdenum and special steels coated with flame-sprayed carbides. Tubes with an internal diameter



Corrosion of zircaloy-2 argon-arc weld fillets (Fig. 4)

of under 10 mm (0·394 in) have been successfully produced.

Drilling—In this process, drilling out the uranium rod to form a tube is done by the BTA-process (Boring and Trepanning Association). In this the oil is forced between the hollow drill and the freshly-bored surface to the cutting edge and returns inside the drill carrying chips with it. The drilling head is self-centring and has hard metal cutting edges. Tests have shown that it is basically possible to drill out solid rod and pipe in lengths of 800–1000 mm (31·50–39·37 in).

Natural uranium dioxide

The Siemens Multi-purpose Reactor and the AVR high-temperature reactor both operate with fuel elements in which the fuel is in the form of UO_2 pellets. Commercial production of such pellets with densities of 10·4 g/cc and over has been and still is the subject of intensive research. One of the biggest headaches was to produce powdered UO_2 of even quality and good sintering properties. This has now been satisfactorily solved. The feed material is tested for grain size, purity and surface area per unit weight and the finished pellets for density, dimensional stability, corrosion-resistance in water, uranium to oxygen ratio, cracks and bursts, density distribution, pore size and pore size distribution, open and closed pores, resistance to thermal changes, diffusion of fission gases etc.

Successful development lead to the setting up of a pilot-scale sintering line with a capacity of about seven tons annually (Fig. 3). The density of the standard pellets is 10·4 ± 0·1 g/cc, the thickness tolerances ± 0·05 mm before and ± 0·01mm after grinding. Autoclave testing at 400°C for 24 h at a pressure of 300 atm brought about no visible changes. Boron content is under 1·3 ppm.

Economic methods requiring little noble gas have been developed for loading the zircaloy-2 tubes with pellets, filling with helium and argon-arc welding the end-caps. The objective of obtaining welding seams completely free of annealing colours and correspondingly good corrosion resistance was reached (Fig 4). The fillet is tested by gamma-radiography with an iridium-192 source, by helium mass spectrometry and in a glycol apparatus. Before the tubes are assembled into an element, they are corrosion-tested and dark oxide surfaced in autoclaves.

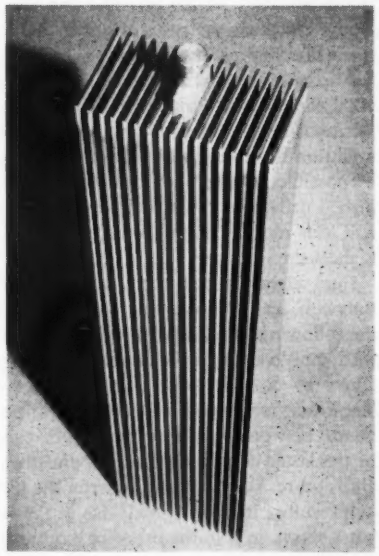
Substantially similar problems have to be solved in the case of the fuel for SNDR-2. Further difficulties are introduced by the handling problems with very thin steel cans (0·1 mm wall thickness) and the welding of end-caps. Various methods, including electron beam welding are being examined for their suitability.

ENRICHED FUELS

In general, fuels for German users are leased—sold in the case of power reactors—by the USAEC within the framework of the bilateral agreement between the AEC and the Federal Government. The enriched uranium hexafluoride is transformed by an American firm into the starting material for the production of fuel elements (U_3O_8, UO_2, U). Work is in hand to carry out the conversion processes from UF_6 at Wolfgang.

Two production methods are being developed for the fabrication of fuel elements for the Argonaut reactors. They are extrusion and the ' picture frame process '. In the first case, enriched U_3O_8 is mixed with aluminium powder and loaded into an aluminium tube closed at one end and vibrated to obtain compacting. The tube, which has an outside diameter of 100 mm (3·94 in) and a wall thickness of about 8 mm (0·315 in), is then sealed and the resulting closed cartridge raised to a temperature of about 450°C. It is then placed in a press and extruded in a strip about 4 m (16·4 ft) long. The aluminium cladding is reduced in thickness to 0·3 mm (0·012 in). The strip is cut up and the U_3O_8/aluminium powder matrix removed at the cut ends to a depth of 3 mm (0·118 in) and the metal sealed together with resin adhesives. Figure 5 shows a fuel element sandwich of 17 strips for the SAR.

In the picture frame process, the mixed powders are made into a strip measuring 80 × 70 × 15 mm (3·15 × 2·76 × 0·59 in) (AEG—Experimental reactor) by pressure. This is then placed in a frame of aluminium and sandwiched between



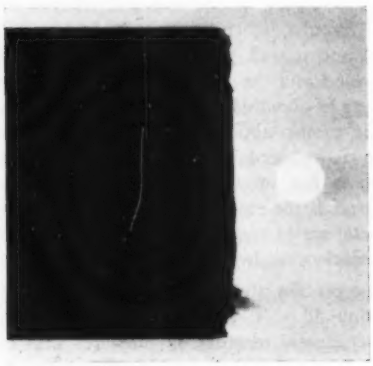
Argonaut elements for the SAR (Fig. 5)

two sheets of aluminium. This is followed by hot and cold rolling. Radiography is used to determine the position of the matrix and the excess aluminium is cut away. Fuel element plates made in this way have the advantage over extruded plates that the matrix is surrounded on all sides by aluminium. One difficulty is in the formation of the matrix ends. For reasons linked with neutron flux the ends of the matrix should be as close to right angles as possible and be free of ' tongues ' of enriched material, or of tongues of aluminium running into the matrix. Figure 6 from normal production, shows that this problem has been successfully solved.

During the development of the picture-frame technique for MTR elements advantage was gained from experience with the Argonaut elements. Fresh research was required for the preparation of a uranium-aluminium alloy and development of processing techniques such as casting, extrusion etc. Finally, it was necessary to learn and master the various ways of assembling the fuel plates into finished elements:

straight or curved plates, welding, pinning. In both cases—cermet and alloyed element—waste processing had to be worked out and placed on an economic footing.

The development of the elements for teaching reactors of very low outputs lead to the use of polyethylene plates containing a dispersion of oxide fuel material. Research was concerned with the selection of the type of polyethylene, the best method of getting a homogeneous mix of fuel material,



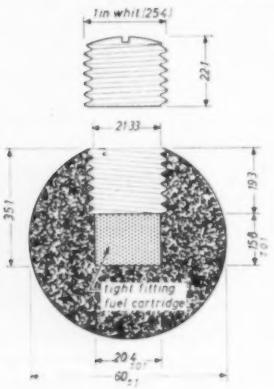
Fuel plate produced by the picture-frame method; X-ray of the end of the matrix (Fig. 6)

the dependence of the physical and technological properties of the plates on the proportions in the mix and the development of economic production methods.

The notes on natural uranium oxide pellets are generally valid for the low enrichment UO_2 pellets for power reactors. Because of the higher price of the raw material, special attention must be paid to keeping irrecoverable losses as low as possible. Where complicated shapes are involved (deeply dished pellets, or rings) which entail a large amount of waste and thus more hold-up in the processing cycle, this is of the highest importance.

Fuel elements for the AKS/Interatom and the SKW/Babcock and Wilcox reactors entail development work in the following areas: alloying slightly enriched uranium metal with molybdenum and aluminium; the production of such alloys by co-reduction; casting plates and tubes of large diameters; nickel-plating fuel surfaces; production of metallic bonds between fuel and aluminium canning in autoclaves. In the latter connexion it was found that the inclusion of a diffusion-resistant coating between the nickel and the aluminium resulted in only a small rise in the bonding temperature but a sharp drop in the pressure required, thus permitting the use of a cheaper autoclave.

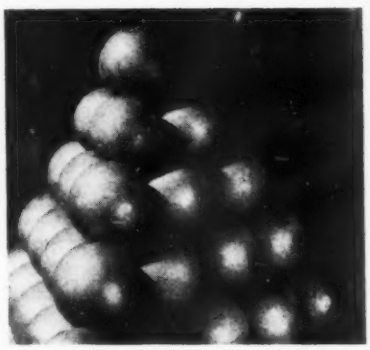
An interesting German reactor concept is the high temperature pebble-bed reactor. Figures 7 and 8 show a cross-section



Cross-section of a high temperature pebble-bed reactor element (Fig. 7)

and the appearance of the fuel elements developed for it. The cylindrical fuel cartridge is made by mixing 20% enriched uranium oxide with graphite powder followed by compression and reacting at high temperature in a vacuum. Proportions are so calculated that the carbon is present in much larger than stoichiometric amounts, which means that the fuel consists of uranium carbide dispersed in graphite. The fuel is inserted in the graphite sphere and a screw-threaded graphite stopper forms the closure. Following this, the sphere is impregnated to reduce permeability to 10^{-6}cm²/s to delay the release of fission product gases to the primary circuit.

During the development of these fuel elements and of economic production techniques, many avenues of research had to be followed. First in importance was the testing of the primary materials, the intermediary products and the finished elements. The important factors in graphite are purity, freedom from cracks, strength, specific gravity, anisotropy, pore and pore size distribution, suitability for impregnation, heat conductivity, and radiation-resistance. In the case of the fuel cylinders, dimensional stability, U-235 content, high melting point, low fission product gas emission, low anisotropy and good heat conductivity are important. The finished sphere



High temperature pebble-bed elements (Fig. 8)

should be as impervious as possible and must not be damaged when dropped into the pebble bed. Abrasion, oxidation and surface contamination by uranium must be kept to a minimum.

GENERAL DEVELOPMENT

Work described so far on fuels and fuel elements is aimed at special fuel element concepts. Apart from this, development work is in progress on more fundamental aspects. Its results will affect later fuel element concepts. In this connexion, the following themes are under study: production of oxide elements by swaging and by other mechanical methods which promise a dense end-product; commercial preparation and processing of uranium monocarbide; grain structure and properties of uranium dioxide; production of UO_2 of high density by arc-melting; neutron activation tests to detect releases of gaseous fission products; heat conductivity of reactor fuels up to 1000°C; inter-metallic compounds of uranium, their preparation and properties; further development of the spherical fuel element of uranium carbide and graphite; plate elements of molybdenum, niobium or steel with UO_2 as fuel material, for a fast breeder reactor.

The aim of fuel element development work in Germany is to catch up with foreign countries as quickly as possible and the foregoing shows that in some areas this has already been achieved. The longer-term objective is to attain full parity and to develop new German concepts.

ATOMIC ENERGY IN THE GERMAN FEDERAL REPUBLIC

THE ROLE OF THE DEUTSCHES ATOM-FORUM

by Dr KARL WINNAKER, President

IT WAS not until the Paris Agreements of May, 1955, that bases were established that enabled the Federal Republic to develop its own nuclear energy programme. In that year, the Federal Ministry for Atomic Energy was set up together with various private organizations. From this there eventually developed, at a later date, the German Atomic Forum.

The Federal Ministry helped in the setting up of the German Atomic Commission which, together with its Technical Commissions and Working Groups, eventually had 500 expert members. Following this, a number of independent research centres were established and sought support from universities and technical colleges.

Once a development programme was under way, supra-regional associations were formed and in 1959, Arbeitsgemeinschaft für Kerntechnik, Düsseldorf; Deutsche Gesellschaft für Atomenergie e.V., Bonn; Verein Atom für den Frieden, Munich, and Physikalische Studiengesellschaft mbH, Düsseldorf, banded together to form the German Atomic Forum.

Forum aims

Its purpose is 'to co-ordinate and develop the co-operative associations working in the Federal Republic in the field of peaceful applications of nuclear energy; to support their work in search of scientific discoveries, in studying technological problems and in the dissemination of information and know-how, as well as to represent these organizations vis-à-vis foreign countries'. The Forum is not exclusive and does not seek legislative or executive action.

These aims were to be achieved by:

(1) Discussions on technical and scientific subjects at national and international sessions.

(2) The establishment of technical standards, recommendations and regulations.

(3) Promoting discussions on aims common to organizations interested in the peaceful development of nuclear energy.

(4) Co-operation with the legislative and executive branches of Federal and State Governments.

(5) Co-operation with foreign Atomic Forums and the international atomic organizations.

(6) Educating the general public on peaceful applications of nuclear energy.

(7) Creation of a permanent atomic exhibition and the establishing of travelling exhibitions.

Complementary to these aims and objectives is the voluntary work of a large number of individuals. This is co-ordinated in the following six working groups of the Forum: Science and Technology; Foreign relations; Public relations and press; Law and administration; Economics and industry and Trade fairs and exhibitions. With these committees, the Forum's particular problems can be settled by experts.

Educational work

To make the general public familiar with both the potential of nuclear energy and its problems, the Forum is co-operating with universities, chambers of commerce and industrial and medical associations; sponsors seminars, discussions and lectures in areas where nuclear plants have been, or are, being built; interests itself in schools, agricultural organizations, insurance companies, research workers and technicians; it seeks to bring this information to all sections of the community and the radio and television networks are used.

Articles and photographs are provided for newspapers, technical periodicals and illustrated publications. Lectures and meetings are arranged. Since its foundation, for instance, Forum members have given 337 lectures to audiences totalling over 40,000. In the same period, 24 seminars and 'university weeks' have been held.

Members of the Forum are taking part in technological research and in recommending rules which should be taken into account when nuclear facilities are set up. They also work on the industrial application of radioisotopes. Another working group aids the German Standards Committee on Radiology in the setting up of units and recommendations on the metrology of ionizing radiations and in considering safety questions. There is very close co-operation with the World Health Organization and with the International Commission on Radiological Protection.

It is of decisive importance for progress that not only industrial firms and individuals have joined together in the various groupings of the Forum but also the established technical and scientific associations. Their members are prepared to work together on joint problems. Our well-proved research organizations will thus be in a better position to fulfil their purpose. New forms for these organizations will therefore not be sought unless they are actually necessary.

Karlsruhe conference

For the first time in West Germany, a full report was made on work on various aspects of nuclear energy at the 'First Technical Session' in Karlsruhe of the Forum. About 1000 participants, including representatives from 14 other European countries, heard 81 reports on the latest position in West Germany in all aspects of nuclear energy. The sessions in Karlsruhe attracted considerable public interest and visitors came from industry, commerce, banks, schools, universities and other organizations. Furthermore, the international contacts of the Forum were strengthened, mainly through personal contact.

The organizational facilities for these contacts and for agreements and exchanges between the atomic associations of the various European countries is provided for by the European Atomic Forum (Foratom). With the co-operation of the German Atomic Forum, Foratom was set up in Paris on July 12, 1960, by organizations from Belgium, France, Italy, Luxembourg, the Netherlands, Switzerland and West Germany. Nuclear organizations in Denmark, Austria, Portugal, and Sweden are also considering joining.

The Atomic Forum is conscious that the reputation of a nation, its economic health, depends on the amount spent on research. Consequently, it is striving to co-operate in the peaceful development of atomic energy and in industrial competition of the nations. In this spirit, the Forum has succeeded in bringing about fruitful co-operation with personalities, institutes, organizations and authorities and thus has laid the foundations for the promotion of its aims in Germany.

ATOMIC ENERGY
IN THE GERMAN
FEDERAL REPUBLIC

This guide covers the activities and interests of utilities, research organizations, study groups, government bodies and private companies in the German Federal Republic

Organizations and companies in the nuclear field

AB BBC-KRUPP Düsseldorf, Königsallee 70 Tel. 8 38 41 Company formed by Brown, Boveri & Cie. AG, Mannheim and Fried. Krupp, Essen
High-temperature gas cooled 'pebble-bed' 15 MWe reactor for AVR Jülich. Proposed design developed from the AVR for a 50 MWt pebble-bed reactor using a gas turbine in a closed circuit. Negotiations in progress with AG Weser (member of the Krupp group) for pebble-bed reactor with gas turbine (10,000 shp)

ADOX FOTOWERKE Dr C. SCHLEUSSNER GmbH Frankfurt (Main) Niedenau 47 Tel. Frankfurt/72 30 41/72 30 44
Film for the IDOS dosimeter for catastrophic levels; double film for protective devices and film badges; special films to order; films for nondestructive testing; advisory service for commercial radiation protection and nondestructive testing using gamma or X-rays

AEG ALLGEMEINE ELEKTRICITATS—GESELLSCHAFT Frankfurt (Main)—Süd 10 Tel. 6 05 21 *Associate Companies:* Telefunken GmbH, Berlin; Hydrawerk AG, Berlin
Construction of the Experimental Nuclear Station at Kahl (Main) on a turn-key basis: installation of the research reactors DIDO and MERLIN for the Atomic Research Centre of North Rhine/Westphalia nr Jülich and supply of equipment such as complete instrumentation of DIDO; construction of the AEG—test reactor for the AEG Nuclear Laboratory nr Grosswelzheim; development and supply of an isochronous cyclotron for the Gesellschaft für Kernforschung mbH in Karlsruhe; design of a nuclear power plant of 150 MWe with a boiling water and a super-heating reactor for the Stüdiengesellschaft für Kernkraftwerke in Hannover; design of a BWR for ship propulsion for the Deutsche Werft AG in Hamburg; supply of a reactor simulator for the Institut für Regelungstechnik of the Technische Hochschule Darmstadt
Accelerators; power station condensers; control systems using radioisotopes; reactor diesel emergency supplies; dosimeters; drives; fans, ventilators; fluid flow meters; flux meters; ionization chambers; phys. laboratory equipment; magnets; nuclear design and construction; complete power reactors; pressure meters; pulse shapers; pulse transmitters; radiation measuring instruments; radiation monitoring plants; reactor design; reactor simulators; recorders; remote control; complete research reactors; semiconductors; servomotors; television surveillance; temperature controls; thermocouples; special tubes; steam turbines; special welding apparatus. *Also able to supply:* b.s.d. equipment; control rod drives; subcritical assemblies; thickness gauges using radioisotopes

AERZENER MASCHINENFABRIK GmbH Aerzen üb. Hameln Tel. 225 *UK representative:* Sturtevant Engineering Co. Ltd.
Rotary piston blowers, meters and pumps.

AGROB, AG für Grob-und Feinkeramik, Ehrang/b. Trier Tel. 60 46/47/48/49
Industrial ceramics

ALUMINIUM-WALZWERKE SINGEN GmbH Singen/Hohentwiel Tel. 34 61
Aluminium, semiproducts and foil

CARL AMBROSIUS Erz-u Schwerspat-grube GmbH Hauptstr. 19, Eisen/Saar Tel. Türkismühle/Saar 227
Heavy concrete shielding materials

ANSCHUTZ & Co. GmbH Kiel-Wik, Mecklenburger Str. 32/36 Tel. 3 16 81
Servomotors

ANTITRON Gesellschaft für Strahlenschutz mbH Dortmund-Mengede, Castroper Str. 43 Tel. 133 52/54
Special shielding concrete

APPARATE-und UHREN-FABRIK AG, Paul Firchow Nachfolger Frankfurt/Main, Baseler Str.
Radiation measuring instruments

ARBEITSGEMEINSCHAFT BADEN - WURTTEMBERG zum Studium der Errichtung eines Kernkraftwerkes (AKS), Stuttgart
(A working group formed by six local companies to study the possibility of constructing a nuclear power plant at Stuttgart). Responsibilities now taken over by the KBWP (see under this name)

ARBEITSGEMEINSCHAFT DEUTSCHER ENERGIEVERSORGUNGSUNTERNEHMEN zur Vorbereitung der Errichtung eines Leistungsversuchs-Reaktors e.V. (AVR), A working group, set up under the leadership of the Düsseldorf Municipal Electricity Works and formed by a number of prominent electric power supply companies in the Ruhr area, for the joint study of problems connected with the erection of nuclear power stations
Have awarded contract to BBC/Krupp for the erection of the 15MW HTGR experimental power station at Jülich and is co-operating with the same company on the development of another 15MW direct cycle pebble-bed design

ARBEITSGEMEINSCHAFT für STRAHLENSCHUTZ Freiburg i. B., Albertstr. 23 Tel 3 52 44
Film dosimeters, evaluation

ARTHUR PFEIFFER GmbH Wetzlar Tel. 34 71
High-vacuum pumps; vacuum meters

ASBEST - und GUMMIWERKE MARTIN MERKEL KG, Sanitasstr., Hamburg-Wilhelmsburg 1 Tel. 75 15 86
Plastic, rubber and asbestos packing and components

ATLAS-WERKE AG Bremen, Postfach 9, Woltermershauser Str. 442/448a, Division Mess-und Analysentechnik Tel. 5 57 57
Pressure controls; mass spectrometers; recorders; vacuum meters; high vacuum valves; leakage monitors; micromanometers; d.c. amplifiers

AUERGESELLSCHAFT GmbH, Berlin N. 65. Tel. 35 05 71
Air filters; humidity meters; protective clothing

AUER - REMY VERTRIEBSGEMEINSCHAFT SELTENE ERDEN, H. BLUM & Co. KG Hamburg 1, Grosse Allee 28 Tel. 24 29 51 *Associated plants:* Th. Goldschmidt AG, Essen-Ruhr; Degussa, Frankfurt-Main *Sales Managers:* H. Blum; E. Jaschinski
Production and sale of europium oxide, hafnium, rare earths, thorium

BBC, Brown, Boveri & Cie. AG Mannheim 1, Postfach A 3 el. 58 91 *Enquiries:* Dr Ing. Karl Deitlhauser
Accelerators; Cooling plants; drives; nondestructive testing; nuclear design and construction; complete power reactors; reactor design; gas turbines; steam turbines; special welding apparatus. *Can also supply:* reactor simulators; complete research reactors

BENNO SCHILDE MASCHINENBAU - AG Bad Hersfeld Tel. 17 01
Fume hoods; ventilators; air conditioning systems; air filters: air conditioning plants; heat exchangers

BERKEFELD-FILTER GmbH Celle Tel. 51 55
Decontamination plants; ion exchange columns; resins for ion exchange; water treatment plants

BIEIWERK GEBR. ROHR Krefeld-Uerdingen. Tel. 4 02 41
Lead shielding materials

BOCHUMER VEREIN AG Bochum Tel. 6 90 21
Steel suppliers

BOPP AND REUTHER GmbH, Mannheim, Waldhof, Carl Reutherstr. 1 Tel. 5 80 91
Valves and butterfly valves for D_2O circuit, helium-circuit, air-circuit. Have supplied valves for FR2

BORSIG AG Berlin-Tegel, Berliner Str. 19-37 Tel. 45 60 11
Air compressors; chemical resistant coatings; power station condensers; cooling gas prification plants; cooling plants; reactor diesel emergency power supplies; ducting; economizers; fans, ventilators; fittings, flanges; fluid filters; gas compressors; gas recombination plants; gates, bulkheads, locks; heat exchangers; ion exchange columns; nondestructive testing; stainless steel; stainless steel castings; steam generators: steam separators; superheaters; tubings, NF metals: tubings, seamless, stainless; steam turbines; special valves; water treatment plants; *Also able to supply;* aluminium finished parts; removable coatings; effluent plants; irradiation channels; lead boxes; nuclear design and construction; reactor loading devices; reactor pressure containers; reactor safety containments; shielded and glove boxes; shielding doors; shielding materials, general, boron, heavy concrete, lead: shielding units, design and construction; shielding windows; thermal columns; transport flasks; coffins; gas turbines; vacuum chambers; reactor quality welding

BRINDI, Ltd, München 23, Ohmstr. 9 Tel. 36 35 36
Radiation measuring equipment

Dr BRUNO LANGE Berlin-Zehlendorf
Measuring instruments supplied to Jülich

BUCHLER & Co Braunschweig, Frankfurter Str. 294 Tel. 2 53 15
Hot laboratories, design; irradiation service; stable isotopes; complete isotope laboratories; lead boxes; manipulators; material testing, radiation sources and equipment; neutron sources; nuclear design and construction; nuclear training devices; radiation protection, consultants; radioactive compounds, processing; radioactive sources; radioactive standards; radioactive substances; radioisotopes, consultants; radioisotope, calibration; radioisotope containers; radioisotopes, encapsulation; radioisotopes, radiation protective storages; radium; radioactive self-luminous materials; shielded and glove boxes; shielding glass; shielding materials, general, heavy concrete, lead; shielding units, design and construction; shielding windows; waste disposal; waste storage

BUNDESMINISTER für ATOMKERNENERGIE und Wasserwirtschaft, Der. Bad Godesberg.
The Federal Ministry of Atomic Nuclear Energy and Water Economy was first formed in 1955 to develop and exploit nuclear energy. It extended its terms of reference to water economy in October 1957
With a staff of some 150 permanent and temporary officials, it deals with legislation and economic matters; administartion; international co-operation; research; engineering; and radiation protection

CARL BAUER SCHRAUBENFABRIK Wuppertal-Cronenberg
Special materials and small parts

CARL CANZLER Düren/Rheinl.
Heavy and light water containers; helium containers; heat exchangers; tubings; ion exchange columns; mixed bed filters etc.

CARL FRUDENBERG Weinheim/Bergstr.
Plastic products

CEAG (CONCORDIA ELEKTRIZITATS AG), Dortmund, Munsterst. 231 Tel. 8 86 11
Air filters for reactors and laboratories

COLORA MESSTECHNIK GmbH Lorch/Württ. Postfach 5 Tel. 483
Chromatography apparatus

CORROKUNSTSTOFF KORROSIONSTECHNIK GmbH Giessen/Lahn Frankfurter Str. 143 Tel. 68 43
Isotope laboratory equipment: fume hoods; glove boxes; shielding; air conditioning; furniture etc.

CSF (COMPAGNIE GENERALE DE TELEGRAPHIE SANS FIL), Direktion Deutschland, München 15, Goethstr. 10 Tel. 53 16 07
Instrumentation, specialist materials

DELBAG-LUFTFILTER GmbH Berlin-Halensee, Schweidnitzer Str. 11 - 16 Tel. 97 76 76; Düsseldorf-Heerdt, Heerdter Buschstrasse 9 Tel. 8181; *UK* Delbag Air Filters Ltd. Uxbridge Tel. 2256
Air filters

DEMAG-ZUG GmbH Wetter (Ruhr), Postfach 67/68 Tel. 20 41/49 A DEMAG subsidiary
Cranes, lifting and conveying devices supplied for research reactors at Garching and Geesthacht

DEUTSCHE ATOMKOMMISSION, Bad Godesberg
Formed in January 1956 to advise the Federal Ministry on all important matters of nuclear research, engineering and economy. Its membership is composed of 29 persons oustanding in science, industry, etc. In addition it is assisted by some 200 other persons working in five different groups: atomic energy law, research and recruitment, technical control of reactors, radiation, financial and social problems. Unlike the Atomic Energy Commissions of other countries, it has no real executive powers

DEUTSCHE BABCOCK & WILCOX-DAMPFKESSEL-WERKE AG Oberhausen (Rheinl.) Tel. 2 45 21 Co-operation with but separate from other B & W companies
Power reactors designed of the gas-cooled graphite-moderated magnox and AGR types. AGR type (150 MWe) being developed for group of utilities in North Germany (Studiengesellschaft für Kernenergiekraftwerke, Hannover). Gas-cooled prototype AGR (10-15 MWe) being designed for the German small reactor development programme. 300 MW magnox type reactor for RWE design with English Electric. Ship reactors 15MW (20,000 shp) gas-cooled reactor being designed for Blohm & Voss, Hamburg; collaborating with B & W (USA) on a PWR design. The 5MW swimming pool reactor of Gesellschaft für Kernenergieverwertung in Schiffbau und Shiffart mbH designed and erected in collaboration with B & W (USA)
Pool lining for storage pond, storage blocks for spent fuel elements and irradiated samples, D_2O heat exchangers, glandless valves, etc. supplied for the FR2, Karlsruhe. Experimental facilities, storage blocks, active circuit ducting, shielding equipment supplied for DIDO at Jülich
Following components designed and erected: heat exchangers and steam raising units; reactor pressure vessels and containments; water pools for reactors; decay tanks and containments; pipe work and storage; water treatment plants; complete auxiliary circuits; irradiation and experimental facilities; 'hot' and 'cold' test loops; blowers; light and heavy concrete shielding; fittings: civil engineering; aluminium finished parts; conveyors; cooling gas purification plants; decontamination plants; drives; gas recombination plants; hot cells; ion exchange columns; leading; tubings in all materials; reactor quality welding

DEUTSCHE EDELSTAHLWERKE AG Krefeld
Stainless steel for reactor components

DEUTSCHE KERNREAKTOR - VERSICHERUNGSGEMEINSCHAFT Köln, Deutscher Ring 11 Tel. 73 48 44
Reactor insurance

DEUTSCHE STEINZEUGWARENFABRIK Mannheim-Friedrichsfeld
Laboratory equipment

DEUTSCHE WORTHINGTON GmbH, Hamburg
Condensers, general fabrication, instrumentation

DEUTSCHEN WERFT AG, Hamburg (DW)
Working with AEG on a direct cycle BWR design study, government aided

DEUTCHES ATOMFORUM, Düsseldorf President:—Prof. D-Ing. K. Winnaker
Formed in 1959 for the co-ordination and development of co-operative work in the field of nuclear energy. Parent companies: Arbeitsgemeinschaft für Kerntechnik, Düsseldorf; Deutsche Gesellschaft für Atomenergie e.V., Bonn; Verein Atom für den Frieden e.V., Munich; and the Physikalische Studiengesellschaft mbH, Düsseldorf

GRUNZWEIG & HARTMANN AG, Ludwigshaven/Rheinl. Tel. 66 42
Insulation and coatings

DINGLERWERKE AG Zweibrücken Tel. 34 51 A DEMAG subsidiary
Reactor structure, biological shield and assembly of complete reactor for FR2 Karlsruhe. Economizers; fans, ventilators; fittings, flanges; gates, bulkheads, locks; heat exchangers: irradiation channels; lead boxes; leakage monitors; radiation protection consultants: reactor pressure vessels and safety containments; servomotors; shielding doors; design and construction of shielding units; thermal columns; reactor quality welding. *Also able to supply*: control rod drives; reactor loading devices; superheaters; transport flasks, coffins, special tubes; special valves; waste storage

DONGES STAHLBAU GmbH, (16) Darmstadt, Mainzerstr. 55, Postschliessfach 449 Tel. 7 43 31
Vessels, cranes, etc. supplied to DIDO AND MERLIN at Jülich. Crane supplied to Farbwerke Hoechst

DRAGERWERK, HEINR. & BERNHARD DRAGER Lübeck, Moislinger Allee 53/55 Tel. 2 58 31 *Sales Manager:* K. Feldhan
Air filters; protective clothing

DURRWERKE AG Ratingen b. Düsseldorf Tel. 36 11
Economizers; heat exchangers; steam generators; steam separators; superheaters. *Also able to supply:* conveyors; reactor quality welding

DYNAMIT NOBEL AG Troisdorf Bez. Köln Tel. Sieberg 50 51
PVC and plastic tubes, plates and general equipment

EDUARD DYCKERHOFF GmbH Poggenhagen-Hannover Tel. 621
Insulating materials supplied for Kahl reactor

EDWARDS HOCHVAKUUM GmbH, Frankfurt/Main—Niederrad, Hahnstr. 34 Tel. 67 33 43
High vacuum pumps and equipment

ELEKTRO SPEZIAL GmbH Hamburg 1, Mönckebergstrasse 7, Tel. 32 17 *Sales Manager:* I. V. Beck, Member of the International Philips Organization (*UK:* Research and Control Instruments Ltd.)
Accelerators; air and water monitoring plants: coincidence-anticoincidence analysers; cooling plants; dosimeters; GM tubes (special); humidity control; hand and foot monitors; nuclear design and construction; photomultipliers: pressure meters; pulse height analysers: radiation measuring instruments; radiation monitoring plants; radioactive sources; recorders: electrical regulators; servomotors; television surveillance; temperature control; thermocouples; timers; special welding apparatus

ELEKTROPHYSIK Dr STEPHAN Bad Godesberg, Plittersdorfer Str. 72 Tel. 6 88 44/45
Planning and installation of isotope laboratories

ELEKTROSCHMELZWERK KEMPTEN GmbH München 22, Bruderstrasse 12 Tel. 22 99 91
Boron shielding materials (boron carbide)

EMIL HELFFERICH NACHFOLGER, Flanchenfabrik Kirkheim-Teck/Württ, Dettinger Strasse 96 Tel. 13 46/48
Fittings; flanges

ERHARDT & SEHMER MASCHINENFABRIK AG A DEMAG subsidiary

ERNST LEITZ GmbH Wetzlar Tel. 851 [*UK* E. Leitz (Instruments) Ltd.]
Nuclear track microscope

ESCHER WYSS GmbH, Ravensburg/Württbg., Postfach 105 Tel. Ravensburg 44 01
Steam and gas turbines; pumps; compressors

ESSENER APPARATEBAU GmbH Essen-Altenessen Tel. 29 23 54/56
Heat exchangers; pressure vessels, storage containers in stainless steel and other materials etc.

FARBENFABRIKEN BAYER AG Leverkusen-Bayerwerk Tel. 35 31 *Chemical Sales:* Messrs Meyerheim and Wilhelm
Resins for ion exchange; activated charcoal: hydrazine compounds; tributyl phosphate: marketing radioisotopes. *Can also supply* terphenyl

FARBWERKE HOECHST AG Frankfurt/Main-Hoecst, Brüningstrasse Tel. 31 05 01
Radioisotopes; heavy water. In association with Siemens Plania (Sigri-Kohlefabrikate) produce reactor graphite

FERNSEH GmbH Darmstadt
Photomultipliers

FERNSTEUERGERATE oHG Zacharia-Oelsch-Meier Berlin-Britz, Jahnstrasse 68-72 Tel. 62 04 51
Recorders; remote handling equipment; servomotors: temperture controls

P. FISCHER & Co. AG Frankfurt/Main Süd
High pressure tubings

FRANKFURT UNIVERSITY — Institute for Nuclear Physics. Facilities:—FRF reactor, 1.5 MeV cascade accelerator and a 5.5 MeV Van der Graaff generator

FRANK & SCHULTE HANDELSGESELLSCHAFT mbH Essen, Alfredstrasse 152 Tel. 4 40 01
Shielding concrete supplied for the FR2 reactor, Karlsruhe; the FRF, Frankfurt and the BER Berlin. Constituents include granulated iron ore, ferro-phosphorus, haematite, ilmenite, barytes and borocalcite

FRIEDRICH UHDE GmbH, Hagen-Haspe, Berliner Str. 36
Rolling mill and steel works equipment

FRIESEKE & HOEPFNER GmbH Erlangen-Bruck/Mfr, Tennenloher Strasse Tel. 25 51/55
Air and water monitoring plants; chromatography apparatus; coincidence-anticoincidence analysers; control systems using radioisotopes; dosimeters; GM tubes (special); lead boxes; leading; hand and foot monitors; neutron counter tubes; nondestructive testing; nuclear design and construction; nuclear training devices; pulse height analysers; radiation measuring instruments; radiation monitoring plants; radiation protection, consulting; complete radiation surveillance car; remote handling equipment; automatic sample changers; scalers, rate-meters; scintillation counters; shielded and glove boxes; thickness gauges using radioisotopes. *Also able to supply*: phys. laboratory equipment; radiation sources for materials testing

Dr Ing. FRANK FRUNGEL GmbH, 400 Sulldorfer Landstr., Hamburg-Rissen Tel. 81 21 51
Generators and pulse transformers

F. J. GATTYS, Ingenieurbüro für chem. Maschinen-und Apparatebau Frankfurt a. Main, Vilbeler Str. 36 Tel. 2 79 57 *Sales Manager*: Wilhelm Zanker
Air and water monitoring plants; conveyors; decontamination plants; hot cells; complete isotope laboratories; materials testing, radiation sources; non-destructive testing; reactor loading devices; optical remote control; automatic sample changers; shielding windows; waste disposal; waste storage; water treatment plants

GEBR. BOHLER & Co. AG Düsseldorf-Oberkassel, Hansa-Allee 321, Edelstahlwerk Düsseldorf Tel. 5 40 71
Austenitic stainless steel; boron steel for nuclear power plants

GEBRUDER KLEES Düsseldorf Tel. 8 48 11/12
Hot laboratory construction and equipment e.g. glove boxes etc.

GERHARD BERGER, Fabrik Elektrischer Messgeräte Lahr/Schwarzwald, Bergstrasse 36 Tel. 32 01/32 02
Servomotors; timers

GESELLSCHAFT für ELEKTROMETALLURGIE GmbH, Düsseldorf
Metals and alloys

GESELLSCHAFT für die ENTWICKLUNG der ATOMKRAFT in BAYERN mbH (GEAB), Munich (Atom Power Development Co.)
Limited liability company formed by four electricity undertakings in Southern Germany, a chemical firm and the Government of Land Bavaria. Three-year contract with Siemens-Schuckertwerke for the development of a D_2O pressure vessel reactor

GESELLSCHAFT zur FORDERUNG der KERNPHYSIKALISCHEN FORSCHUNG e.V (GFKF) name now changed—see under: *Kernforschungsanlage Jülich des Landes Nordrhein—Westfalen —e.V.*

GESELLSCHAFT für INDUSTRIELLE FERTIGUNGEN der CHEMIE und PHYSIK mbH Düsseldorf, Grafenberger Allee 165 Tel. 68 22 77/78
Compressors and pumps

GESELLSCHAFT für KERNENERGIEVERWERTUNG in SCHIFFBAU und SCHIFFAHRT mbH (GKSS) *Location:* Geesthacht, Hamburg. Joint company set up in 1956 constituted from 33 firms representing a wide range of German industrial and financial interests - to further the applications of nuclear energy to shipbuiding and navigation
Reorganized 1960—capital increased to DM80 million with shares distributed as follows: the four north German coastal states of Lower Saxony, Bremen, Hamburg and Shleswig-Holstein—DM20 million, industry comprising shipyards, shipping companies, engineering concerns, banks and insurance companies—DM39 million, Federal Republic—DM21 million. Funds for further capital investments and to cover operating costs will be supplied by the Government and the States in the ratio 60 to 40
Director General: Mr Geyer *Comm. Manager:* Dr M. von zur Mühlen
Director of the Institute for Reactor Physics: Dr E. Bagge
Collaborating with Interatom, since 1959, on the development of an OMR. Has called for tenders (to be submitted by 31 Jan. 61) from German shipbuilders for test vessel of 10.000shp: 22,000dwt, 177m long, 24m wide, 9.6m deep—completed by 1965 at around DM35 million

GESELLSCHAFT für LINDE'S EIMASCHINEN AG Höllriegelskreuth b. München, Dr Carl von-Linde-Strasse Tel. 79 06 55
Application of low-temperature techniques for gas purification processes. Helium purification systems supplied for reactors under construction. Air compressors; air conditioning systems; cooling gas purification plants; gas compressors; heavy water production plants; special welding apparatus

GEA, GESELLSCHAFT für LUFTKONDENSATION mbH Bochum, Königsallee 43-47 Tel. 3 72 51
D.O/H, heat exchangers in aluminium Air cooled water coolers and condensers. Secondary water coolers supplied for MERLIN and DIDO in North-Rhine-Westphalia

GESELLSCHAFT für NUCLEONIC und ELECTRONIC mbH (NUCLETRON) München 2, Dachauer Strasse 111 Tel. 55 08 80 *Agents for:* Laboratories Inc., Kay Electric Co., Non-Linear Systems Inc., Varian, Evershed & Vignoles
Shielding units; pulse height analysers; control systems using radioisotopes; laboratory equipment; photomultipliers; vacuum pumps; scalers, ratemeters; scintillation counters

GEVEL GmbH Düsseldorf, Schadowplatz 12 Tel. 8 49 81
Radiation and general instrumentation. Agents for ACES, Charleroi

GEWERKSCHAFT BRUNHILDE Hannover-Utze, Heiligerstrasse 17 Tel. 1 35 18
Ore dressing plants; pulse shapers; pulse transmitters; radiation measuring instruments; complete radiation surveillance car; scintillation counters; uranium concentrates; waste disposal

GEWERKSCHAFT KERAMCHEMIE Siershahn/Westerw., Tel. Ransbach 0 26 23 *Sales Manager*: Hubert Hintzen
Chemical resistant coatings; removable coatings; floor coatings; protective claddings

GLASFASER GmbH Düsseldorf Tel. 1 41 56
Insulating materials for Karlsruhe etc.

Th. GOLDSCHMIDT AG, Chemische Fabriken Essen, Söllingstrasse 120 Tel. 2 12 31
Europium oxide

P. GOSSEN & Co. GmbH Erlangen, Nägelbachstrasse 25 Tel. 33 41 *Sales Manager*: Heinz C. Dittberner
Electrical regulators; temperature controls

FRITZ H. GOTTFELD GmbH, Köln-Lindenthal Tel. 41 85 94
Isotope containers

GRAETZ-RAYTRONIC GmbH Altena (West f.), Graetzstrasse Tel. 32 41
Dosimeters; radiation measuring instruments

GRUN & BILFINGER AG, Mannheim, Carl-Reiss-Platz 1 - 5 Tel. 45 91
Heavy concrete shielding materials

GRUNDIG RADIO-WERKE GmbH Fürth/Bay., Kurgartenstrasse 37 Tel. Nürnberg 7 66 21
Television surveillance (supplied to CEA, France); nuclear training devices; dosimeters

GUSSSTAHLWERK WITTEN AG Witten/Ruhr, Auerstrasse 4 Tel. 21 41
Steel suppliers

GUSTAV F. GERDTS KG Bremen, Hemmstrasse 130 Tel. 8 42 91 *Technical Sales Manager*: Dr Ing. Walther Simon *UK Representative*: I.V. Pressure Controllers Ltd.
Fittings; steam separators

GUTEHOFFNUNGSHUTTE STERKRADE AG Werk Sterkrade Oberhausen-Sterkrade Tel. 60141 *Head of Nuclear Technology Division*: Dr Alfons Thiel Licensing Agreement with General Atomics for design, construction and sale of all types of GA reactors
30-ton reactor tank built for FR2, designed and built 90-ton heat exchanger for the Kahl BWR. Air compressors; circulators; chemical resistant coatings; power station condensers; conveyors; economizers; fans, ventilators; gas compressors; gas recombination plants; gas separators; heat exchangers; nondestructive testing; ore dressing plants; steam generators; steam separators; superheaters; gas turbines; steam turbines; reactor quality welding. *Can also supply*: complete power reactors: reactor design; reactor pressure containers; reactor safety containments; complete research reactors; transport flasks, coffins

HAHN-MEITNER-INSTITUT für KERNFORSCHUNG, Berlin. Governed by the Berlin Education Senate and works in close liaison with the Free University and the Technical College. Conducts research on nuclear chemistry—main facility BER reactor—mathematics and biology

HALLWACHS & MORCKEL, Fabrik für Betriebsmessinstrumente Bensheim Tel. 31 16.
Fluid flow meters; pressure meters; electrical regulators; remote control; temperature control

HANS-HEINRICH-HUTTE GmbH Frankfurt/Main, Reuterweg 14 Tel. 55 05 71 *Sales Manager*: H. Mische
Lithium and its salts; rubidium, caesium and their compounds

HANS WALISCHMILLER Meersburg/Bodensee Tel 223
Air filters; centrifuges; chemical resistant coatings; cranes, lifting and conveying devices; bellows expansion joints; fans, ventilators; fittings, flanges; fume hoods; gates, bulkheads, locks; hot cells; construction and design of hot laboratories; irradiation channels; complete isotope laboratories; chem. phys. laboratory equipment; laboratory furniture; lead boxes; manipulators; radiation sources for material testing; protective clothing; radiation protection, consultants; radioisotopes containers; radioisotope encapsulation; radioisotopes, radiation protective storages; optical remote control; remote handling equipment; shielded and glove boxes; shielding doors; shielding glass; shielding materials, general, heavy concrete, lead, tungsten; design and construction of shielding units; shielding windows; waste storage; special welding apparatus

HARTMANN AND BRAUN, Mess und Regeltechnik, Frankfurt/Main-West 13, Grafstr. 97 Tel. 77 06 11
Light electrical, precision mechanisms, instrumentation

HENSCHEL-WERKE GmbH Kassel
Feedwater tanks; shielding water tanks; fuel handling equipment

M. HENSOLDT & SOHNE, Optische Werke AG Wetzlar, Postfach 207, Gloelstr. 3-5 *Sales Managers*: *Home*, E. A. Genrich; *Overseas*, H. Häuser *UK representative*: Degenhardt & Co. Ltd London
Optical remote viewing equipment

W. C. HERAUS GmbH Hanau Tel. 2 42 51 *UK Representative*: Fleischman (London) Ltd.
Vacuum arc melting furnaces and electron beam melting furnaces. Furnaces of the former type supplied to many countries. The latter type, important for high m.p. metals (e.g. niobium, tantalum) supplied to Euratom and CEA/France. Furnaces used for producing zircaloy-2 and other high-quality alloys. Vacuum pumps; vacuum meters; valves; electron beam welding etc.

HERFUTH GmbH Hamburg-Altona Tel. 89 33 63
Radiation detection instrumentation

AG A. HERING Nürnberg. Herrnhutterstrasse 33-35 Tel. 57 87 41/44
Air conditioning plants; air conditioning systems; vacuum chambers; water treatment plants

HILGER AND WATTS Ltd., Dortmund-Horde, Seydlitzstr. 38 Tel. 4 08 71

HOCHTIEF AG, Hoch-und Tiefbauten, vorm Gebr. HELFMANN Essen, Rellinghauserstr. 55/57 Tel. 2 01 21
Shielding materials and units

HOCHLIST AG für Hoch-und Tiefbauten Niederlassung Frankfurt/Main, Bockenheimer Landstr. 24 - 26
Shielding. Contractors for German DIDO and MERLIN and Kahl reactors

ANDREAS HOFER Hochdruck-Apparatebau GmbH Mulheim (Ruhr) Postfach 535, Zeppelinstrasse 14 Tel. 4 61 34 *Sales Manager*: Dr-Ing. Werner Köttnitz
Air compressors; circulators; gas compressors; pumps, diaphragm, seal-less; special valves

HONEYWELL GmbH Frankfurt/Main, Rheingaullee 112 Tel. 77 07 87 (subsidiary of the Minneapolis Honeywell Regulator Co.) *Sales Manager*: A. Abolins
Complete reactor instrumentation supplied to the Munich F1 reactor through AMF. Computors; control systems using radioisotopes; fluid flow meters; flux meters; humidity control; phys. laboratory equipment; nuclear training devices; pressure meters; radiation measuring instruments; radiation monitoring plants; reactor simulators; recorders; electrical regulators; remote control; remote handling equipment; scalers, ratemeters; semiconductors; servomotors; temperature controls; thermocouples; vacuum meters; special valves

IDEAL-STANDARD GmbH Bonn, Poppelsdorfer Allee 114 Associate of American-Standard, USA; Rheinkälte, Düsseldorf; Ideal-Standard, Bonn
Complete research reactors (UTR). Cooling plants etc.

INDUSTRIEBERATUNG in FRAGEN der PHYSIK Köln, Teutoburger Str. 3 Tel. 3 58 68
Control systems using radioisotopes; GM tubes; level gauges using radioisotopes; nuclear training devices; radioisotopes, consultants

INDUSTRIE-WERKE KARLSRUHE AG Karlsruhe, Gartenstrasse 71 Tel. 2 29 11
Bellows expansion joints supplied to Berkeley, Hunterston and Hinkley Point for main ducts

INSTITUT für STRAHLENTECHNOLOGIE der LEBENSMITTEL-to be set up at the Karlsruhe centre to complement the work of the Federal Research Office for the Preservation of Foodstuffs

INTERATOM Internationale Atomreaktorbau GmbH Bensberg/Köln, Postfach Tel. 27 91 *Parent Companies*: DEMAG AG, Atomics International *Sales Manager*: Dr. L. Fischer-Zernin
Planning assistance to AI on the construction of the L-54 reactors at Frankfurt/Main and Berlin. Participation with AI in the KBWP preliminary design contract for an OMR 150 MWe nuclear power station in southern Germany. Design contract with GKSS of Hamburg on an OMR marine propulsion unit. Homogeneous research reactors; industrial applications of radioisotopes; design and supply of reactor accessories and services, including: control rods; decontamination of rooms and equipment; hot cells: nondestructive testing: nuclear training devices; radioactive sources; radioisotope containers; reactor loading, devices: shielding units; sub-critical assemblies; thermal columns; transport flasks, coffins; waste disposal; waste storage

INTERMETALL Gesellschaft für Metallurgie und Elektronik mbH Freiburg i. Br., Hans-Bunte-Strasse 19 Tel. 31495 *Sales Manager;* Robert Stasek. Associated with the Clevite Corp., Cleveland, USA
Semiconductors

ISOTOPENLAB. Dr Sauerwein, Düsseldorf-Eller, Harfstr. 148 Tel. 78 62 16
Material testing, tracer experiments, services supplied to DIDO

ISOTOPEN - STUDIENGESELLSCHAFT - cooperative association of German industrial companies to develop the uses of radioisotopes in all areas of technology. Facilities being built at the Karlsruhe Centre to conduct its own research programme and carry out research contracts

Th. JANSEN GmbH Armaturen-und Maschinenfabrik Rohrbach, Saar
Isolating valves for reactor primary gas circuits; fittings

JENAER GLASWERK SCHOTT & GEN. Mainz/Rhein, Hattenbergstrasse Tel. 8161
Shielding glass (*Sales Manager;* Walter Day); glass-to-metal bonding & special glass (*Sales Manager*, Erich Schulze). Research centres in Germany, France, Italy, the UK, the USA, Switzerland and Australia have been supplied

KERNFORSCHUNGSANLAGE JULICH des LANDES NORDRHEIN—WESTFALEN-e.V.
Originally set up in 1953 as the Gesellschaft zur Förderung der kernphysikalischen Forschung e.V. to plan, construct and operate the Jülich Nuclear Research Centre. Composed of the scientific universities of the State of North rhine-Westphalia (Bonn, Cologne and Münster) and some of the important firms in the nuclear field. Facilities: DIDO, MERLIN type reactors and various institutes for Reactor Materials, Radiochemicals, Plasma Physics, etc.

KERNKRAFTWERKE BADEN - WURTTEMBERG Planungsgesellschaft mbH, Stuttgart
Recently formed to succeed AKS for the placing of contracts for reactor design studies. A contract is about to be signed with Interatom for a 150MW OMR power plant study. With the proposed site near Mosbach (southern Germany), if design is acceptable KBWP will then decide on construction as part of Euratom programme, completion by 1965

KERNREAKTOR BAU-und BETRIEBSGESELLSCHAFT (KI) set up in 1956 to acquire, collect and apply scientific and technical data on the peaceful development and applications of nuclear energy. Built and is operating the Karlsruhe Nuclear Research Centre operates the FR2 reactor and Institute for Neutron Physics

KERNREAKTOR Bau-und Betriebs-Gesellschaft mbH Karlsruhe Weberstrasse 5 Tel. 2 68 25/27
Research and development company

KERNREAKTOR - FINANZIERUNGSGESELLSCHAFT. Special jointly-owned company to Capital DM60 million (Federal Republic 30%; Baden-Württemberg 20%; Industry 30%). Running expenditure: Federal Republic/Baden-Württemberg 75/25 ratio, latter's share limited to DM7·5 million annually

GESELLSCHAFT für KERNFORSCHUNG (KI) set up in 1959 to handle the finances and facilities at the Karlsruhe Nuclear Research Centre not included in the original plans of KI and in which industry does not wish to participate. Participants: Federal Republic-75%, Baden-Württemberg-20%, upper limit DM20 million. Estimated funds for 1961 DM 120 million
Operate: Institutes for Radiochemistry, Nuclear Techniques, Radiobiology, Hot Chemistry, Electronics, Solid State Physics, Reactor Materials and Nuclear Physics; Isotope Laboratories, a 50MeV cyclotron, zero energy Argonaut; School for Nuclear Techniques

KIENZLE APPARATE GmbH Villingen (Schwarzwald), Prinz Eugen Strasse 20 Tel. 32 81 *Sales manager*: Dipl.-Ing. Gerwalt Polzin *UK Agent*: Radiatron
Digital printers

KIREM, Kernstrahlungs-, Impuls-und Reaktor-Messtechnik GmbH Frankfurt/Main, Bockenheimer Landstrasse 101 Tel. 77 18 63/77 19 33 (A co-operative organization between Hartmann & Braun AG and Messrs. Landis & Gyr)
GM tubes; ionization chambers; level gauges using radioisotopes; linear amplifiers; hand and foot monitors; dosimeters; proportional counters; radiation measuring equipment; air and water monitoring equipment; flow meters; thickness gauges using radioisotopes; reactor period meters; scalers; ratemeters; photomultipliers; scintillation counters; radiation protection warning; reactor control instruments

RICH. KLINGER GmbH Idstein/Taunus Postfach 69
Packing and seals in p.t.f.e.

KLOCKNER-HUMBOLDT-DEUTZ AG Werk Humboldt, Köln-Kalk, Wiersbergstrasse Tel. 67 71/ *Sales enquiries*: Dr-Ing. Lothar Wenz
Absorbers; centrifuges; conveyors; reactor diesel emergency power supplies; fans, ventilators; gates, bulkheads, locks; heat exchangers; ore dressing plants

KLOCKNER - MOELLER, ELEKTRIZITATS-GmbH Bonn, Immenburgstr. 7-11 Tel. 5 29 01
Regulation and control equipment. *Have supplied* Mary Kathleen Uranium, Bonn synchrocyclotron etc.

KLOCKNER-WERKE AG, Duisburg, Mulheimerstr. 50 Tel. 39 01
Compressors

KLOCKNER-WERKE AG, Georgsmarienwerke Osnabrück Bessemerstr. 1 Tel. 32 21
Flange ring supplied for the Kahl FR2 reactor. Heat exchangers; reactor pressure containers; reactor safety containments; stainless steel; steam generators; transport flasks, coffins; waste storage; reactor quality welding

AUG. KLONNE, Dortmund, Westfalendamm 72 Tel. 2 53 51
Boilers; tubing; mech. handling equip. etc.

Dipl.-Ing. ULRICH KNICK Berlin-Zehlendorf, Katherinenstrasse 2-4 Tel. 84 23 47
Electronic measuring equipment (supplied to German reactor institutes)

ALBERT KNOTT München 23, Muffatstrasse 8 Tel. 33 14 80 *Agents for*: The Victoreen Instrument Co., Jordan Electronics, Inc., Precision Radiation Instruments, Inc., Crystals, Incorporated, George A. Philbrich Researches Inc.
Computors; GM tubes; semiconductors; pulse transmitters; pulse height analysers; ionization chambers; phys. laboratory equipment; neutron counter tubes; photomultipliers; automatic sample changers; radioactive sources; semiconductors; scalers, ratemeters; recorders; dosimeters; radiation monitoring instruments; geological radiation measuring instruments; scintillation crystals; scintillation counters; special GM tubes

KOHLENSCHEIDUNGS-GESELLSCHAFT mbH Stuttgart-W., Johannesstrasse 41-45 Tel. 6 81 56/ 59 *Owned by*: Combustion Engineering Inc., New York & Mathias Stinnes AG, Mulheim/ Ruhr
Heat exchangers; oil-fired superheaters and standby boilers

KOLN-WESSELINGER EISENBAU mbH Wesseling bei Köln Tel. 24 41
Mechanical handling equipment and construction

J. KOTTERMANN KG Fabrik f. Laboratoriumsapparate und-möbel, Hänigsen üb. Lehrte Tel. 247/248 *Sales Manager*: J. Freres
Air conditioning plants; fans, ventilators; fume hoods; design and construction of hot laboratories; complete isotope laboratories; chem. phys. laboratory equipment; laboratory furniture. *Can also supply*: air filters; fittings, flanges: floor coatings; radioisotopes, radiation protective storages; shielded and glove boxes; waste disposal

H. KRANTZ LUFTTECHNIK Aachen-Richterich, Postfach Tel. 3 70 44
Air conditioning systems; air conditioning plants supplied to German reactors

KROPFMUHL-RINGSDORFF AG für Sondergraphite, Bad Godesberg-Mehlem, Konigswinterestr. 1 Tel. Bad Godesberg 1 20 01
Graphite for all nuclear and reactor engineering purposes

KSB Klein, Schanzlin & Becker AG Frankenthal/ Pfalz Tel. 25 11 *Sales Director*: Dipl.-Ing. G. Kleiber
Air compressors; circulators; fittings, flanges; pumps, seal-less, canned, vacuum; switchboards; special valves. Pumps and switchboards supplied to research and power reactors in all European countries, the UK and Japan

KUNSTSTOFFTECHNIK GmbH Troisdorf/Köln Tel. Siegberg 65 55/56
Plastic valves, pumps; air conditioning plants; general isotope laboratory equipment

LABORATORIUM Prof. Dr BERTHOLD Wildbad/Schwarzwald, Calmbacher Strasse 22 Tel. 587 *Sales Manager*: Kurt Leininger
Air and water monitoring plants; coincidence-anticoincidence analysers; control systems using radioisotopes; dosimeters; GM tubes (special); level gauges using radioisotopes; hand and foot monitors; neutron probes; nuclear training devices; pulse height analysers; radiation measuring instruments, radiation monitoring plants; radioactive sources; automatic sample changers; scalers, ratemeters; scintillation counters; thickness gauges using radioiotopes

F. LANDENDORF Hamburg 39, Muhlenkamp 59 Tel. 27 34 42. *Associated* with Chempump Corp, USA
Canned pumps, D_2O organic liquids

LAND GOVERNMENTS
Advisory boards and commissions on atomic energy maters. Baden-Württemberg: (1) Advisory board on nuclear energy (2) Specialist commission on radiation. Bavaria: State commission on the peaceful uses of atomic energy. Berlin Atomic Commission. Schleswig-Holstein; permanent study commission

LEWA, HERBERT OTT KG, Leonberg b. Stuttgart, Eltingerstr. 58-60 Tel. Leonberg 72 41
Precision mechanisms, e.g. proportioning pumps

LEYBOLD-HOCHVAKUUM-ANLAGEN GmbH Köln-Bayental, Bonner Strasse 504 Tel. 47 16 Subsidiary of E. Leybold's Nachfolger *UK Representative:* Leybold-Elliott Ltd.
Manufacturers of high-vacuum equipment. Projects include: steel cells for isotope distribution, Freie Universität Berlin; Vacuum equipment, large pump sets, special liquid hydrogen containers for CERN; engineering design and supervision of the radioactive laboratories and hot cells at the Atomic Centre Jülich; member of the German group together with Lurgi Gesellschaft für Chemotechnik mbH, and Friedrich Uhde GmbH for the Eurochemic Reprocessing Plant at Mol; design of dismantling cell for the Reactor Centre Jülich; manipulators for various German and foreign research centres and industry. *Also can supply:* b.s.d. equipment; decontamination plants; effluent plants; lead boxes; reactor loading devices; design and construction of reprocessing plants; transport flasks, coffins; waste disposal

LUDWIG GREFE Ludenscheid i.W.
Flow Measuring equipment

LUFTFAHRT-TECHNIK GmbH Kommanditgesellschaft Düsseldorf, Berliner Allee 69 Tel. 8 07 83/85 Representatives of Bristol Siddeley
Circulators; control rod drives; gas compressors

LURGI Gesellschaft für Chemotechnik GmbH, Frankfurt/Main, Gervinusstr. 17/19 Tel. 55 06 51
Engineering and services, e.g. ore treatment plant, reactor engineering

LUWA GmbH, Frankfurt/Main, Hanauer Landstr. 200/202 Tel. 4 85 41
Air conditioning for reactors, heating and ventilation equipment filters

MAINZ UNIVERSITY—Institute for Inorganic and Nuclear Chemistry. Main facility: Triga II reactor

MAN MASCHINENFABRIK AUGSBERG-NURNBERG AG, Werk Nürnberg Nürnberg 2 Tel. 4 89 81 Co-operation agreement with GEC
Air conditioning plants; air conditioning systems; power station condensors; cranes, lifting and conveying devices; reactor diesel emergency power supplies; economizers; fans, ventilators; gates, bulkheads, locks; heat exchangers; neutron diffraction apparatus; reactor pressure vessels; reactor safety containments: super heaters; gas turbines; steam turbines. *Also able to supply*: complete power reactors; complete research reactors; steam generators; steam separators; transport flasks, coffins. MAN Augsburg works are building a neutron diffraction spectrometer for Yugoslavia

MANNESMANN-EXPORT GmbH Düsseldorf, Mannesmannufer Tel. 82 01
Reactor pressure vessel supplied for Kahl. Another pressure vessel for the Dragon project now under construction. Chemical resistant coatings; reactor pressure vessels; stainless steel; special tubes; tubings, seamless, stainless; reactor quality welding

MANNESMANN ROHRLEITUNGSBAU GmbH, see Mannesmann-Export RUHRSTAHL AG Heinrichshütte Hattingen/Ruhr Tel. 35 42
Reactor pressure vessels, heat exchangers, containments tubing, thermal shielding, plate, vacuum chambers, equipment supplied for Kahl reactor and CERN synchrocyclotron

Dr L. C. MARQUART AG Beuel/Rheinl. Tel. 4 19 44
Cadmium, bismuth products

MASCHINENBAU - AKTIENGESELLSCHAFT BALCKE Bochum, Marienplatz 5 Tel. 6 90 11
Suppliers to SSW, BBC, AEG, etc. Cooling plants; fluid filters; gas compressors; heat exchangers; vacuum pumps; water treatment plants. *Can also supply:* air conditioning plants; vacuum chambers

MATERIAL-PRUFSTELLE FRITZ H. GOTTFELD Koln-Lindenthal Tel. 41 85 94
Nondestructive testing; isotope consultants

MAX PLANCK INSTITUTE for PLASMA PHYSICS—research foundation set up near to the Garching Research Station by the Max Planck Company for the Advancement of Science. Works closely with Euratom, Jülich, the Plasma Institute of Hanover Technical High School (building) and university working groups at Kiel, stuttgart and Brunswick

MEDIZINISCHE TECHNIK. Ing. AUGUST HOFMANN, Bamberg, Stuffenbergstr. 140 Tel. 44 25 *Agent for* Radiation Counter Laboratories Inc. USA
Multi-channel analysers, etc.

E. MERCK AG, Darmstadt Tel. 80 21
Uranium, thorium etc.

METALLGESELLSCHAFT AG Frankfurt/Main, Reuterweg 14 Tel. 55 05 71 *Affiliated with* Vereinigte Deutsche Metallwerke AG, etc.
Aluminium and alloys; bismuth; cadmium; nuclear purity calcium; magnesium; uranium, concentrates

METALLSCHLAUCH-FABRIK PFORZHEIM Pforzheim Tel. 18 06
Heat exchangers, bellows, expansion joints, tubes etc.

METZENAUER & JUNG Wuppertal
Instrumentation and control supplied to Riso, RCN etc.

MOTOREN-WERKE MANNHEIN AG Mannheim 1, Postfach 1563 Tel. 5 80 81
Reactor emergency diesel supplies for various research centres including Karlsruhe Technische Hochschule, Jülich etc.

MUNK AND SCHMITZ VERTRIEBSGESELLSCHAFT mbH, Köln-Poll, Poller Kirchweg 92-104 Tel. 8 30 01
Vacu-blast equipment

NEUE ARGUS GESELLSCHAFT mbH Ettlingen/Baden, Goethestrasse 15 Tel. 27 34
Fittings; valves supplied for reactors in Germany

NEW-YORK HAMBURGER GUMMI-WAAREN COMPAGNIE, angeschl.: Dr Heinrich Traun & Söhne GmbH Hamburg-Harburg 1, Nartenstrasse 19 Tel. 77 10 31
Chemical resistant coatings; removable coatings: moulded parts in special materials; seals, packings; tubings, nonmetallic. *Can also supply*: bellows expansion joints

ALFRED NEYE ENATECHNIK Darmstadt, Elisabethenstrasse 17 Tel. 7 63 59/ 7 28 30 *Exclusive licence for West Germany from* Ekco/Dynatron Ltd UK. Eldorado Electronics USA, Franklin Electronics USA
Nucleonic measuring apparatus

NUCLEAR GmbH Düsseldorf, Florastrasse 16 Tel. 1 93 77 *Commercial Manager*: Walter Gärtner *Agents for* Hawker Siddeley Nuclear Power and TEM Engineering Ltd. for gamma irradiation equipment
Isotope devices for nondestructive materials testing; gamma irradiation equipment

NUKEM. Nuklear-Chemie und Metallurgie GmbH Wolfgang bei Hanau/Main Tel. 69 11 *Founder Companies*: Degussa, Rio Tinto Management Services, Mallinckrodt Chemical Works
Producers of fuel elements of natural and enriched uranium, breeder elements of thorium and reflector elements. Fuel elements have been supplied for the FR2, Siemens reactor at Garching and the AEG research reactor at Grosswelzheim. Elements for the BBC-Krupp reactor are being produced. *Also selling agents* for Degussa-Wolfgang Industrieofenbau industrial furnaces; facilities for refining uranium and producing fuel elements have been supplied to the Agentinian, Spanish, Indian and Italian Atomic Energy Authorities, and to the Sumitomo Atomic Energy Industries Inc.

OSRAM GmbH München 2 Tel. 22 88 91
Lighting; shielding materials, tungsten, molybdenum etc.

Dr C. OTTO & COMP. Gesellschaft mit beschränkter Haftung Bochum, Christstrasse 9 Tel. 3 73 21
Centrifuges; gas compressors; heat exchangers; ion exchange columns; ion exchange resins; water treatment plants. *Can also supply*: gas separators; ore dressing plants

PERMUTIT AKTIENGESELLSCHAFT Berlin-Schmargendorf, Auguste-Viktoria-Strasse 62 Tel: 89 03 86
Decontamination plants; ion exchange columns; ion exchange resins; water treatment plants; heat exchangers

PHISIKALISCH - TECHNISCHE WERKSTATTEN Dr PYCHLAU KG, Freiburg im Breisgau, Lorracherstr. 7 Tel. 3 17 10
Radiation detection and monitoring equipment

PHOENIX-RHEINROHR AG, Vereinigte Hüttenund Rohrenwerke, Düsseldorf, August-Thyssenstr. 1 Tel. 82 41 *Sales Manager*: Walter G. Geue
Fittings, flanges, heat exchangers; nondestructive testing; special tubes, seamless, stainless. *Can also supply*: economizers; reactor pressure vessels; shielding units; superheaters; waste storage; reactor quality welding

PHYWE AKTIENGESELLSCHAFT Göttingen, Levinstrasse, Flugplatz Halle 61 Tel. 2 43 38/39
Air and water monitoring plants; centrifuges; dosimeters; chem. phys. laboratory equipment; laboratory furniture; lead boxes; neutron sources; nuclear training devices; radiation measuring instruments; radiation monitoring plants; radioactive substances; shielded and glove boxes; timers

PICKER & HARTING GmbH Espelkamp-Mittwald/Westfalen
Isotopes, radiation detection equipment

PINTSCH BAMAG AG Butzbach/Hessen. Tel. 41 01
Decontamination plants, reactor and chemical engineering. *Have supplied* Karlsruhe, Jülich Kahl etc.

POTSCHKE & Co. oHG, Vertriebsgesellschaft für Strahlungsmessgeräte Frankfurt/Main 1, Postfach 2766 Tel. 55 16 88 *Sales Manager*: Adolf K.-H Pötschke
Equipment supplied to AEG, BBC-Krupp and Kernreactor Bau-und Betriebsgesellschaft. Air and water monitoring plants; coincidence-anticoincidence analysers; control systems using radioisotopes; digital printers; dosimeters; GM tubes (special); design and construction of hot laboratories; humidity controls; ionization chambers; complete isotope laboratories; lead boxes; leakage monitors; level gauges using radioisotopes; hand and foot monitors; neutron counter tubes; neutron probes; nuclear design and construction; nuclear training devices; photomultipliers; protective clothing; quartz glass and equipment; radiation measuring instruments; radiation monitoring plants; radiation protection, consultants; complete rad ation surveillance car; radioisotopes, consultants; radioisotopes, radiation protection storages; recorders; automatic sample changers; scalers, ratemeters; scintillation counters; scintillation crystals; shielded and glove boxes; shielding doors; shielding glass; shielding materials, lead; designed construction of shielding radioisotopes; timers. *Can also supply*: chromotography apparatus; reactor diesel emergency power supplies

PRAZISIONSMESSGERATE RSV Dr H. RITZL and Dr R. SEITNER oHG, Hechendorf/Pilsensee, Inningerstr. 17
Photomultipliers; pulse height analysers, etc.

PREUSSISCHE BERGWERKS-und HUTTEN-AKTIENGESELLSCHAFT Hannover 1, Leibnitzufer 9 Tel. 1 44 71/75
Cadmium; fittings, flanges; lead shielding materials; tubings, NF metals, nonmetallic, seamless, stainless; water treatment plants

QUARTZ & SILICE (DEUTSCHLAND) GmbH, Bad Pyrmont/Mains Hylligen Born 1 Tel. 442
Scintillation crystals

RADIUM-CHEMIE Dr v. Gorup KG Frankfurt/Main, Untermainkai 34 Tel. 33 62 10 *Associated with* Buchler & Co., Braunschweig
Static elimination, radiography and thickness measurement; gamma sources for medicine and industry; lead boxes; transport flasks, coffins; remote handling equipment

REAKTORPUMPEN HALBERG-WEISE AG, Heidelberg, Treitschkestr. 3 Tel. 2 43 23
Pumps

REAKTORSICHERHEITSKOMMISSION (RSK)—Reactor Safety Commission Headed by Prof. Dr Ing. J. Wengler of Farbwerke Hoechst and supported by specialists from many fields, including: radiation biology, air purification, shipbuilding and ship propulsion, radiation medicine, civil engineering, nuclear physics and nuclear chemistry

REICHERT-ELEKTRONIK GmbH & Co. KG Trier, Postfach 743 Tel. 743
Air and water monitoring plants; coincidence-anticoincidence analysers; computers; dosimeters; ionization chambers; neutron choppers; pulse height analysers; pulse shapers; pulse transmitters; radiation measuring instruments; radiation monitoring plants; automatic sample changes; scalers, ratemeters; scintillation counters; servomotors

REKUPERATOR KG Dr-Ing. SCHACK & Co. Düsseldorf Tel. 49 00 55
Heat exchangers, superheaters, air conditioning plant etc.

RHEINISCH - WESTFALISCHES ELEKTRIZITATSWERK AG (RWE), Essen
Largest electric supply company in the Federal Republic. Responsible for the 15MW Kahl BWR; has looked at proposals for two Magnox reactors from British companies and another proposal for a 240MW BWR, with nuclear superheat

RHEINSTAHL—with AEG and the Stadwerke Düsseldorf—formed a reactor building group to build MERLIN and DIDO type reactors at the Jülich Nuclear Research Centre

ROCA APPARATEBAU GmbH Düren/Rheinl. Tel. 33 81
Heat exchanger for CERN synchrocyclotron

ROCHLING'SCHE EISEN-u. STAHLWERKE GmbH, Völklingen/Saar Tel. Völklingen 35 11
Hot rolled steel; castings; wire and wire products

PAUL KAHLE ROHRLEITUNGSBAU GmbH Düsseldorf
Tubing for German MERLIN and Kahl reactors

RUHRSTAHL AG HEINRICHSHUTTE Hattingen/Ruhr Tel. 35 41
Boilers and pressure vessels: shielding units: *have supplied for* FR2 reactor, Bonn synchrocyclotron etc.

SAMESREUTHER & Co. GmbH, Butzbach/Hessen, Kaiserstr. 13 - 15 Tel. 40 11
Boilers

SANDSVIKSTAL GmbH Düsseldorf, Heerdter Landstrasse 229/33 Tel. 5 55 88/89 *Sales Manager:* Ingmar Wendschalg
Special tubes; tubings, seamless, stainless; zirconium and alloys semiproducts and finished parts

AUG. SCHNAKENBERG & Co. GmbH Wuppertal-Barmen, Beyenberger Strasse 148/168 Tel. 5 10 55
Absorbers; air conditioning plants; chemical resistant coatings (with lead and PVC); fume hoods: gas separators; complete isotope laboratories; lead boxes; leading; shielded and glove boxes; transport flasks, coffins; tubings, nonmetallic, lead-lined steel pipe; waste storage. Have supplied to Jülich

SCHOELLER - BLECKMANN STAHLWERKE GmbH Düsseldorf Tel. 2 52 41/43
Stainless and boron steel, control rods, tubes etc.

SEITZ-WERKE GmbH Kreuznach (Rheinl.) Tel. 70 01 *Export enquiries:* Dr E. K. Reinhardt
Decontamination plants; effluent plants; fluid filters

SERO PUMPENFABRIK GmbH Meckesheim-A bei Heidelberg Tel. 531
Pumps

SHIPPING COMPANIES

HOWALDTSWERKE HAMBURG AG (HWH)
Working with Siemens Schuckertwerke on PWR design study, government aided

BLOHM & VOSS, Hamburg (B & V)
In conjunction with the Deutsche Babcock & Wilcox, are interested in the development of a gas-cooled design, government aid to be ratified

AG WESER, Bremen (AGW)
In co-operation with BBC/Krupp, interested in a design for HTGR pebble-bed reactor. Financial support under negotiation

BREMEN VULCAN (BV)
Preliminary work by MAN on an AGR design

SIEMENS & HALSKE AG Karlsruhe West, Rheinbrückenstr. 50 Tel. 89 51
Nuclear and conventional instrumentation for FR2, Karlsruhe; Siemens-Argonaut-Reaktors at Munich and Karlsruhe; Siemens - Untersuchungsreaktor SUR 100. Air and water monitoring plants; chromatography apparatus; control rod drivers; dosimeters; fluid flow meters; flux meters; GM tubes; humidity controls; ionization chambers; complete isotope laboratories; nondestructive testing; pressure meters; pulse height analysers; radiation measuring instruments; reactor simulators; recorders; electrical regulators; remote handling equipment; scintillation counters; scintillation crystals; servomotors; television surveillance; temperature controls; thermocouples; special valves

SIEMENS-SCHUCKERTWERKE AG Erlangen, Werner-von-Siemens-Str. 50 Tel. 811 Associate companies; Siemens & Halske AG, Siemens-Reiniger-Werke AG, Sigri-Kohlefabrikate GmbH, Siemens-Bauunion GmbH
SAR 1 Garching, SAR 2 Karlsruhe. Accelerators; circulators; computors; power station condensers; control rods and drives; control systems using radioisotopes; reactor diesel emergency power supplies; dosimeters; magnets; radiation sources for materials testing; nuclear design and construction; complete power reactors; reactor design; reactor loading devices; electrical regulators; complete research reactors; semiconductors; servomotors; subcritical assemblies; gas turbines; steam turbines; special welding apparatus. Have designed a multipurpose reactor (see article this issue)

SIGRI-KOHLEFABRIKATE GmbH Meitingen ü. Augsberg Tel. 321 New company formed by Farbwerke Hoechst and Siemens-Plania *Sales Manager:* Dr Fritz Jeitner
Reactor grade graphite of all types and densities; Supplied to BBC-Krupp, AEG, SSW, Kernreaktorbau, B & W etc. Reflector graphite supplied for DIDO at Jülich. Graphite for advanced gas-cooled reactors, impermeable, coated etc. Also development of silicon carbide, molybdenum silicide and ceramics

Dr SLEVOGT & Co. Weilheim/Obb. Tel. 26 38
Resonance spectrometers, electromagnets etc.

Dipl.-Ing. GEORG SPINNER Elektro-Physikalische Geräte GmbH München 2, Erzgiessereistr. 33 Tel. 55 46 72/59 27 71/55 76 39
Radio frequency apparatus; coaxial components for power lines; coaxial high frequency plugs

STAHL-ARMATUREN SIEPMANN GmbH KG Belecke/Möhne
Valves supplied to Trawsfynydd

STAHL-UND ROHRENWERK REISHOLTZ GmbH, Düsseldorf-Reisholtz Tel. Düsseldorf 7 02 71
Heat exchangers, containment, tubing, etc. for reactors

STAHLWERKE SUDWESTFALEN AG Geiswed/Sieg. Tel. Siegen 71 81
Stainless and boron steel

STEINHAUS GmbH Mülheim/Ruhr Postfach 779
Special flooring

L. & C. STEINMULLER GmbH, Rohrendampfkessel-und Maschinenfabrik Gummersbach/Rhld. Tel. 28 51/58
Heavy water cooler supplied for Halden, decontamination system for Kernreaktorbau-u. Betriebs-Gesellschaft mbH, boiling and pressurized water loop for Ispra. Decontamination plants; heat exchangers; steam generators; steam separators; superheaters

RICHARD H. STERN Frankfurt/Main Tel. 27953 *Agents for:* Technical Measurement Corp. USA, Anton Electronic Laboratories USA, Isotopes Specialities Co. USA, Nuclear Corp. of America, Semi Elements Inc. USA
Radiation detection and general instrumentation. Isotopes and isotope equipment. *Have supplied* Jülich

STROHLEIN & Co., Fabrik Chemischer Apparate Düsseldorf, Aderstrasse 93 Tel. 1 00 25
Air conditioning plants: air conditioning systems; centrifuges; removable coatings; effluent plants; fans, ventilators; fittings, flanges; fume hoods; hot cells; hot laboratories, design and construction; irradiation channels; phys. chem. laboratory equipment; laboratory furniture; lead boxes; manipulators; radioisotope containers; radioisotopes, radiation protective storages; shielded and glove boxes; shielding materials, general, concrete, lead; shielding windows

STUDIENGESELLSCHAFT zur FORDERUNG der KERNENERGIEVERWERTUNG in SCHIFFBAU und SCHIFFAHRT e. V.—the research organization for carrying out the development work of GKSS. Built the Forschungsreaktor Geeshacht FRG—full power 1960. Attached is the Institute of Reactor Physics

STUDIENGESELLSCHAFT für KERNKRAFTWERKE GmbH (SKW), Hannover
(Study group for nuclear power plants formed by electric power companies in Hamburg, Hanover, Berlin and Dortmund)
Co-operating with AEG on a 150MW BWR design study and on a 150MW AGR study by Deutsche Babcock and Wilcox

SUDDEUTSCHE KABELWERKE ZWEIGNIEDERLASSUNG DER VEREINIGTE DEUTSCHE METALLWERKE AG, Mannheim, Waldhofstr. 244 Tel. 5 40 51
Polythene and copper tubing

SUNVIC REGLER GmbH, Solingen-Ohligs, Hackhauserstr. 66a Tel. 1 42 25 *Associate* of AEI Instruments Div. *Agent for* Nuclear Equipment Ltd.
Radiation detection and general instrumentation

TECHNISCHEN HOCHSCHULE MUNCHEN
Munich Technical High School—Laboratory of Applied Physics—are running the Garching reactors critical Oct. 1957
Working with the Riso centre in Denmark on soft gamma spectra emitted after neutron absorption and with Karlsruhe centre

TELEFUNKEN GmbH, Ulm/Donau Tel. 6 19 21
Radiation detection equipment and general instrumentation; lead shielding

ALFRED TEVES, Machinen-und Armaturenfabrik KG Frankfurt/Main, Rebstöcker Str. 41-53 Tel. 33 01 71 *Chief Sales Executive:* Heinz Köhler
Air conditioning systems; cooling plants; remote control; remote handling equipment; special valves; heat exchanger supplied for the secondary circuit of Argonaut-type reactor

TOTAL-GERATEBAU GmbH Ladenburg/Mannheim Tel. 29 01
Radiation measuring instruments

TUCHEL-KONTAK Heilbronn/Neckar Tel. 8 58 90
Electrical regulators

FRIEDRICH UHDE GmbH, Dortmund, Deginstr. 10 - 12 Tel. 20 71
Equipment for chemical engineering, furnaces etc.

VEREINIGTE ALUMINIUM-WERKE AG Bonn Tel. 3 17 41/46
Aluminium and alloy reactor tanks, tubes, and cladding

VEREINIGTE BLEIWERKE GmbH & CO. Stolberg Rheinl., Binsfeldhammer 40 Tel. 30 31
Isotope equipment; shielding materials

VEREINIGTE DEUTSCHE METALLWERKE AG, Hauptniederlassung, Heddernheimer Kupferwerk, Frankfurt/Main Tel. 52 00 21
Specialist materials, e.g. boral, zirconium, aluminium

VEREINIGTE ECONOMISER-WERKE GmbH. Hilden, Eichenstr. 2 Tel. 27 21 27
Heat exchangers; tubing, etc.

VEREINIGTE KESSELWERKE AG Düsseldorf, Werdener Str. 3 Tel. 7 42 61
Heat exchanger for 15 MW reactor, construction of MERLIN reactors at Jülich, steam generator for the BBC-Krupp high temperature reactor. Power station condensors; coolant gas purification plants; decontamination plants: economizers; gas separators; heat exchangers: nondestructive testing; steam generators; steam separators; superheaters; tubings, non-metallic, NF, seamless, stainless; waste disposal; waste storage; reactor quality welding

VEREINIGTE LEICHTMETALL - WERKE GmbH, Bonn am Nordbanhof Tel. 3 19 11
Aluminium semi-products

VEREINIGTE WERKE Dr RUDOLF ALBERTI & Co. Lohr/Main Tel. 573
Shielding units and materials; isotope equipment

Dr VIRUS Kerntechnik GmbH Bonn, Rosenburgweg 20 Tel. 2 49 24 *Sales Manager:* Dr D. Schulz
Chromatography apparatus; ionization chambers; lead boxes; radiation protection, consultants; radioisotopes, consultants; radioisotope containers; radioisotopes, radiation protective storages; design and construction of shielding units. Specializes in the supply of isotope measurement equipment

J. M. VOITH GmbH, Maschinenfabrik Heidenheim/Brenz
Air conditioning plants; circulators; cooling plants; hydraulic and mech. couplings; drives; fans, ventilators; fittings; gears; special valves

WABAG Wasserreinigungsbau Kulmbach
Cooling and effluent treatment plants

WALBERSDORF SONDERMASCHINENBAU Siegen/Westf., Bahnhof Eintracht 1 Tel. 2 23 06
Circulators; pumps, canned, diaphragm, liquid-metal, seal-less for high temperature applications

JOHANNES ERHARD H. WALDENMAIER ERBEN Süddeutsche Armaturenfabrik Heidenheim/Brenz, Meeboldstr. 22 Tel. 38 81/4
Fittings; valves

HERMANN WALDNER KG. Wangen im Allgau, Tel. 83 83
Laboratory furniture

WAYSS & FREYTAG KG Frankfurt/Main Neue Mainzer Strasse 59 Tel. 2 00 11 Associated with Karrena GmbH
Shielding units and construction in concrete etc.

K.-H. WEIGAND Messtechnik GmbH Erlangen Tel. 58 41/2
Electrical regulators

WILKE-SAUERBAU, Bonn (Rhein) Dransdorfer Weg 25, Tel. 3 73 47
Linings for tanks, etc.

ZENTRALWERKSTATT GOTTINGEN GmbH Göttingen, Bunsenstrasse 10 Tel. 2 35 97/2 49 48
GM tubes; hand and foot monitors; pulse height analysers; radiation measuring instruments; scalers, ratemeters; scintillation counters; shielding units. *Can also supply:* air and water monitoring plants: coincidence-anticoincidence analysers; ionization chambers; pulse shapers; pulse transmitters; raidation monitoring plants

This month's items are devoted to work in the German Federal Republic

Fuel element test facilities

German AGR studies

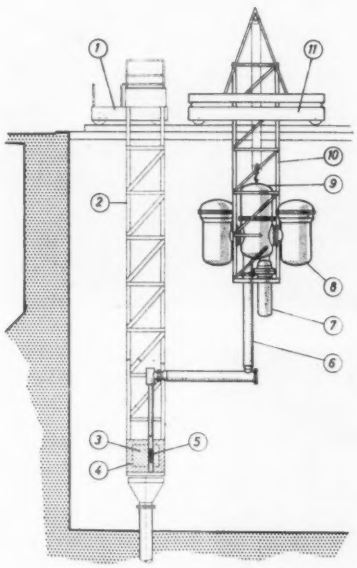
MUCH OF the work at the Deutsche Babcock-Werke on the advanced gas cooled reactor over the past two years has been concerned with fuel element development and design. The fuel element currently under examination has a cylindrical graphite sleeve with 19 fuel rods of stainless steel containing UO_2 pellets. The sleeves are 31·5 in long, 4·1 in inner diameter and 5·1 in outer diameter. The rods which form a 19-rod cluster have an operating surface temperature of 620°C.

For neutron flux measurements, the laboratory uses a Battelle (Frankfurt) accelerator with a neutron yield of more than 5×10^{10} fast neutrons/sec combined with a graphite block of 3·9 ft sides (Fig. 1). Fuel elements are arranged in 25 channels using UO_2 enriched to 2%. An original type element is installed in the centre of the flux area while the remaining 24 are simplified by distributing the enriched fuel in the form of UO_2 powder over all the channels. Measurements carried out include: intracell flux distribution between the rods and on local areas, thermal utilization, the effects of control rods near an element, fine flux distribution with partially inserted control rods, and the effect of removing fuel elements from an adjacent channel. Other physical problems investigated are: calibration of reactivity effect, the study of basic diffusion constants of graphite at different temperatures, measurements of thermal diffusion length in heterogeneous media, and measurements on sub-critical reactor systems to establish accurate reactor calculation methods.

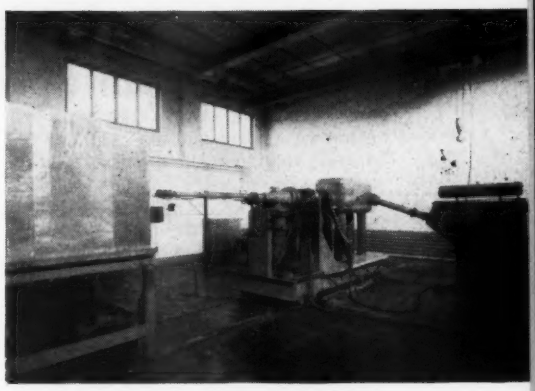
Out-of-pile rigs

For the thermodynamic performance of fuel elements, rigs have been installed that include low pressure and high pressure loops. Used mainly for pressure loss characteristics, the low pressure loop, because of the small gas mass flow of about 3 lb/sec and the short lengths of pipe, reaches stable conditions in a relatively short time. For more detailed investigation is the high pressure loop that uses CO_2, air or N_2, at 6 to 80 atmos., at a flow rate of 18·3 lb/sec and attains a temperature of 400°C with a heat input of around 300 kW.

Gas flow through the test section can be reverted and the wall temperature of all 19 rods is measured by sliding thermocouples that save time of registration and adjustment. Thermocouple adjustment in the axial and radial directions is effected by means of two motors located within the pressure pipes so as to prevent leakage. The control motors receive impulses from a temperature recorder. The Demag one-stage centrifugal blower used has an oil gland that incorporates the bearings of the blower axle and takes charge of the sealing against a pressure of 80 atmos. A secondary gas circuit installed between the oil gland and the primary circuit prevents oil contamination and, at the same time, cools the casing.



5 MW reactor test loop 1 reactor support bridge 2 reactor support tower 3 reactor core 4 reflector 5 test specimen 6 loop piping 7 heat exchanger 8 blower 9 secondary containment. 10 loop support tower 11 loop support bridge (Fig. 2)



Pulsed neutron generator and experimental arrangement with graphite pile (Fig. 1)

In-pile loop tests

For testing coolants, moderator materials and fuel elements under reactor conditions, a gas rig is under construction (Fig. 2) that will be used in Hamburg's 5 MW swimming pool reactor. The neutron flux at loop position is $2·7 \times 10^{13}$ n/cm²sec, and due to this relatively low flux, a burn-out of only some 100MWd/t of UO_2/month can be attained. Nevertheless, these tests will allow unsuitable designs to be eliminated since gas pressure, temperature and flow are in accordance with the reactor conditions.

In-pile test loop data

coolant	CO_2 or N_2
gas flow rate	0·2 kp/sec
gas pressure	80 atmos (max.)
heat in test section	25 kW (max.)
heater capacity	10 kW (max.)
heat removal in exchanger	30 kW (max.)

The test section (5), which consists of an austenitic stainless steel pressure tube contained in a zircaloy-2 protective tube, is inserted into the reactor core (3) in such a way that three sides are surrounded by fuel elements and one side by the graphite reflector. Exchange of the element is carried out by unscrewing a plug from the upper part of the test section which also serves as a thermocouple duct. The coolant is circulated by two Demag blowers (8) connected in series so that, in the event of a failure, the stand-by unit can take over immediately.

The heat exchanger (7) is designed as a multiloop cooler and a heater is installed for the fine adjustment of the coolant temperature entering the test section. Automatic recorders measure continuously temperature, pressure and gas flow and these are connected to an alarm system, a control circuit and the reactor instrumentation so that automatic shut-down occurs in the event of a serious failure. ★ 280

German graphite production

high temperature applications

Reactor graphite of high purity and homogeneity is in production at the Griesheim plant of Sigri-Kohlefabrikate. Since carbon cannot be melted under normal pressure, shaped carbon bodies are formed by moulding or extrusion. These ' green ' bodies, containing coke grains enveloped by a suitable binder of high carbon content, are first carbonized to convert the binder to pure carbon, after which they are graphitized at a temperature of around 3000°C. During the graphitization, graphite crystallites in the coke form simultaneously with a reduction of the distance between the crystallographic layer planes.

Almost all the elements which are found as impurities in graphite have a neutron cross-section much higher than that of pure carbon. Nuclear grade graphite can be manufactured either by using very pure raw materials and avoiding contamination during fabrication; or by flushing the graphite at around 3000°C with halogens and sweeping out the impurities in the form of halogenides. By using the latter method over the past two years, Sigri have reduced the ash content to 10-20 ppm (99·999%C) thus keeping neutron activation at the lowest level. (See Table 1.)

TABLE 1 *Calculated and measured (pile-oscillator) neutron cross-sections*

GRAPHITE nuclear grade	ASHES BORON ppm	ASHES BORON ppm	NEUTRON CROSS-SECTIONS (mbarn)* (a)	(b)	(c)
SIGRI-AMT	22	0·02	3·80	3·86	3·61
SIGRI-AMC	45	0·12	4·08	4·12	3·88
SIGRI-ARS	200	0·12	4·45	4·48	4·15

* for monoenergetic neutrons of 2200 m/sec
(*a*) calculated from impurities (pores filled with nitrogen); (*b*) measured in air ; (*c*) without nitrogen filling.

Irradiation tests of German reactor grade graphites in the US, France and in Germany indicate that Sigri products are completely equivalent with respect to neutron irradiation to the best available grades elsewhere.

The problem of making impermeable graphite, a material required for use with liquids and gases, was tackled soon after the war based on experience gained in the I. G. Farben plant at Bitterfeld and on developments in the Siemens-Plania laboratory at Ratibor. A resin-impregnated graphite ' Diabon ' was therefore put into production that had its use in the chemical industry for coolers, heat exchangers, pumps, valves and linings. Because of the thermal decomposition of the resin impregnation, however, ' Diabon ' cannot be used above 160°C. Its main application in the nuclear field is for graphite reflectors under water, such as in the Argonaut-type reactors; or for containers of the pneumatic feeding system for the irradiation section; or for pipe and pump material in water cooled and moderated reactors.

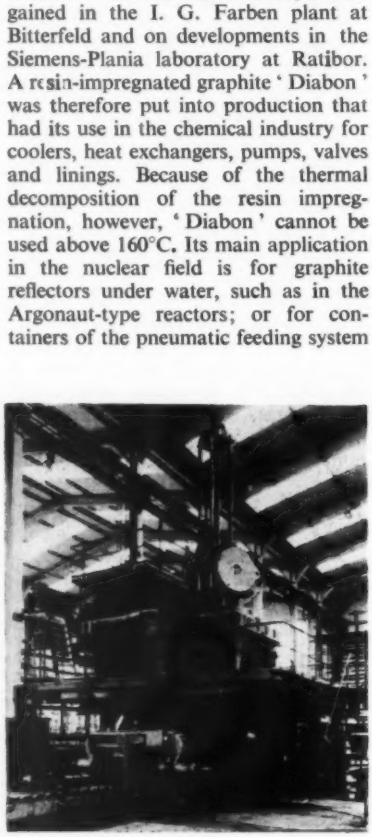
Checking alignment in a trial assembly of a graphite reflector

For use at high temperatures—in advanced gas cooled reactors, for canning materials, or for the fuel element pebbles of the BBC-Krupp Schulten reactor—impermeability had to be achieved by pure carbon. Two methods were examined: deposition of pyrolitic carbon by thermal decomposition of gaseous carbon compounds; and impregnation by a liquid carbon compound which is then thermally decomposed.

For the cases of specially developed Sigri fine-grain materials, the most favourable conditions and materials for the impregnation are determined by the distribution function of the macropores measured by mercury-porosimetry. In the case of liquid impregnation, the temper and coking conditions are carefully selected and balanced.

Impregnation through the gaseous phase results in impermeability mainly at the surface and the graphite so treated can easily be damaged mechanically. All shaped bodies so treated have to be outgassed at temperatures above 2000°C in order to avoid the reduction of impermeability under service conditions. The liquid impregnation process however results in homogeneous sealing over the whole cross-section. Sigri who have been developing the liquid impregnation method find that final permeabilities of the order 10^{-5} cm² sec^{-1} can be achieved for a variety of shapes, and they have produced spherical elements with a permeability of 10^{-6} cm² sec^{-1} and graphite pipes with permeabilities of 10^{-7} cm² sec^{-1}.

Useful work has also been done to inhibit the oxidation of graphite in an oxygen containing atmosphere and techniques have been developed for applying silicone carbide and special silicide coatings. ★ 281



Hydraulic extruding press (above)

Graphitizing furnaces

Heat Exchanger for Kahl

improved degasification

The 90-ton steam heat exchanger for the 15MW Kahl reactor, designed by Gutehoffnungshütte, is arranged vertically and is fitted over the reactor to allow vaporization, and condensation in the exchanger, to take place in normal circulation, trouble free. Steam, at 1000 lb/in²g and 286°C, enters the primary inlet and is carried to the outer side of the tubes to be condensed on their outer lateral surfaces, giving off heat. The tubes themselves are braced to prevent bending by three supporting plates that also act as baffles to increase the steam path in the converter. Heat transfer is increased when the steam, flowing as a cross-current on the tubes, clears away the condensation drops.

To avoid the strong disturbances in condensation cause by oxyhydrogen gas (around 5 lb/h) formed during the gamma decomposition of water, the exchanger is designed to allow the gas to collect under the top tube plate and below the three supporting plates from where it is carried off laterally through drain nozzles fitted in the outer shell. For better degasification, additional pipes have been fitted, particularly on the lower pipe ends directly over the condensate surface, where an additional drain nozzle has been fitted.

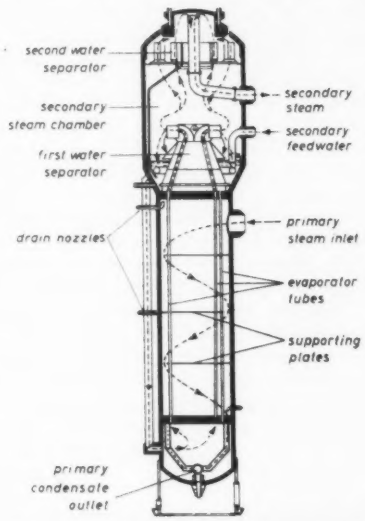
The feed water enters at the level of the first water separator and mixes with the water lying over the upper tube plate. The water passes through the gravity down-pipes and rises up through the evaporator pipes. The heat released through the condensation of the primary steam effects a partial vaporization and the resultant water vapour mixture passes into the upper steam chamber. Thus the first water separator contains a rough division of steam and water.

This separated water re-mixes with the feed water and is led again through the down pipes to the vaporizing circuit. The vapour rises slowly to the second separator, where the steam is separated from any drops still remaining, and passes, with the residual moisture (about 0·1%) to the turbine.

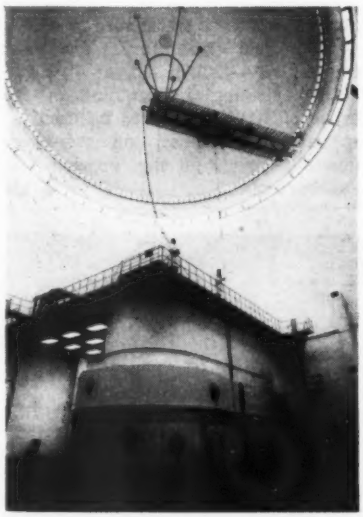
The shell is made of ferritic steel, with the primary side surface facing in high grade steel. The two tube plates into which the heat exchange pipes are rolled and welded are 7 in thick, with both sides protected with a chrome-nickel-steel weld deposit. The pipes are made from 0·07%C, 22%Cr, 5%Ni, 1·5%Mo and 0·06%Co steel to match the thermal expansion of the ferretic shell.

Assembly and fabrication were carried out in clean conditions, the inside of the shell was pickled and flushed out with Aquadest, and the pipes were cleaned out separately. Using distilled water, secondary side pressure tests were made up to 1710 lb/in²g, followed by primary side pressure tests up to 188 lb/in²g. Further measurements were taken for elongation on both the inside and the outside and under water. Other tests were made for deflexion and expansion.

★ 282



The Kahl heat exchanger is 40 ft high. In the secondary steam chamber, diameter 8·2 ft, at a pressure of 665lb/in²a and 258°C, 105 tons/h of steam is produced. With a reduced load of 10% of rated load, the steam pressure rises to 968lb/in²—primary pressure and temperature remaining constant



The cupola of Garching's reactor hall is formed from a 4 in thick concrete skin. Fitting suitable overhead lifting tackle raised interesting design problems

Heavy water production

gas liquefaction

Drawing from 50 years' experience in gas liquefaction, Linde have developed successfully for the large scale production of heavy water, a low temperature process based on the distillation of liquid hydrogen. The contract given by Farbwerke Hoechst specified an installation yielding heavy water of 99·8% atomic purity. Another unit using electrolytic hydrogen as the feed gas is under construction for India.

The process developed uses, as feed gas, crude hydrogen from ammonia synthesis and it is progressively freed of condensable impurities, especially nitrogen, during the preliminary cooling down stages. Three successive distillation columns are used: first for the production of a 96%H 4%D mixture, then 10%H 90%D and finally deuterium at 99·8%.

Linde have also taken over the industrial production of helium liquefiers, one of which has been supplied to the Munich research centre. They supply other gases, particularly xenon for bubble chambers and are also concerned with low temperature techniques that combine adsorption and extraction for the continuous, or batch, removal of contaminants formed in reactor gas containers. In addition, tanks for the storage of liquid gases can be provided up to 16,500 gal. capacity.

★ 283

Fuel-lift for Munich

Garching's novel crane

The oval shaped dome of Garching's 1MW FRM reactor building, an ellipsoid of 98 ft diameter and 98 ft high, created a problem in design for suitable lifting tackle. Demag overcame the problem by fitting a monorail to attachments in the reinforced concrete wall to take a double-beam crane with a capacity of five tons. The bridge of the

crane hangs from the centre of the ceiling on a rotary tubular structure which is itself free to turn.

The crane structure has a special travelling crab with a free run of nearly 34 ft for speeds varying from 56 to 443 ft/min, and a turning speed that can be varied between 26 and 108ft/min. Three lifting cables are provided, the two outer ones work together synchronously to lift five tons, the third can be operated independently to lift 2·5 tons. The crane is used for the insertion and removal of fuel elements, for moving the separation wall and for other services.

★ 284

Welding fuel elements

electron beam used

Neat weld seams of high density and gas free are now possible. The new plant, the BW500, developed by Heraus and about to be supplied to Euratom, uses the principle of electron bombardment and a vacuum environment. The accelerating voltages of the electrons, between 50 and 100 kV, are sufficient to obtain deep penetration. Electron 'guns' are also available for special applications requiring accelerating voltages up to 200 kV. As the welding energy is highly focused, high welding speeds are obtained that minimize structural changes in the heated metal.

The plant operates under a vacuum of 10^{-4} to 10^{-5} mm Hg, and the absence of flux metal additions and inert gas, ensures an uncontaminated welding seam. Operation is fully automatically controlled to give welds of uniform depth, width and external appearance in quantity production.

Designed mainly for welding plugs on reactor fuel elements of reactive metals such as zircaloy-2, the vacuum chamber may be equipped with a mobile charging drum capable of carrying 12 fuel elements in lengths up to 39·37 in. If required, the elements may be filled with inert gas in the same chamber and the plug opening closed by arc weld. Alternatively, the drum may be replaced by an installation for the blunt welding of sheets up to 15·75 in.

Heraus introduced the technique for melting metals by electron bombardment in high vacuum in 1959, since when the range of installations available covers from 5 to 200 kW output (see *Nuclear Power*, Sept. 1960, p. 115). Other achievements made in their own laboratories include the development of vacuum arc melting furnaces giving high purity metals, metals with high melting points—molybdenum, titanium, zirconium, alloy steel, nickel and cobalt-base high temperature alloys and stainless steels. Furnaces are now available ranging from the L200, with a normal ingot capacity of 44 lb, to a special type for handling a 40 ton ingot. ★ 285

Reactor pressure vessels

materials research

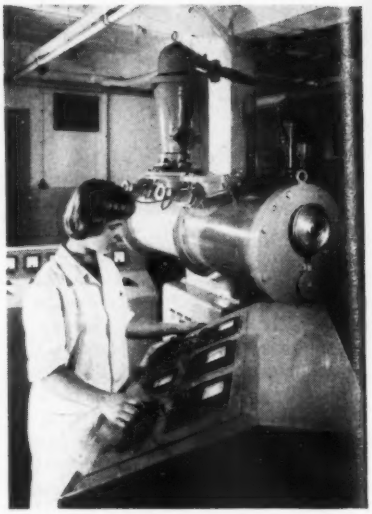
As an alternative to the tendency towards thicker pressure vessel walls, Mannesmann are working on a multi-layer design. The wall is built up from thin shell rings; the individual shell portions, at suitable temperature differentials, are telescoped by means of a press, and thus shrink tightly together. As an alternative to zircaloy-2 for fuel rod canning, they are also designing very thin-walled tubes with thicknesses up to 0·1 mm, made of stainless austenitic steels. Tubes are being produced with very close tolerances in the dimension of 13·6×0·2 mm.

Other problems being investigated are hot and cold deformation of steels; the interdependence of microstructure, surface conditions, and corrosion resistance of stainless steel tubes; and the stress distribution of containers subjected to internal pressure—the latter tests being specifically related to the Kahl installation. Studies are also being conducted on high-alloyed creep-resistant steels for use at high temperatures and high pressure. ★ 286

Advanced reactor studies

Zirconium hydride

Under a long-term development programme, Interatom are studying an advanced reactor system of high power density that uses sodium as a coolant, uranium carbide as a fuel and zirconium hydride as moderator. There is reason to believe that such a compact and reliable reactor system, permitting high coolant temperatures, is feasible. For further improvement in the thermal efficiency of the system, and to avoid the design problems associated with the sodium-heated steam generator, it is planned to investigate the possibility of replacing the intermediate sodium circuit by a turbine unit operating on a mercury steam cycle. ★ 287



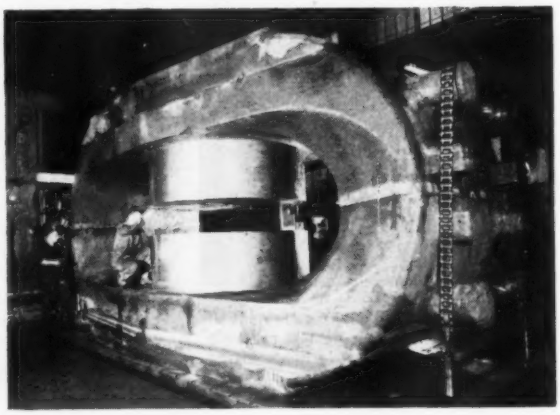
In the Heraus electron beam welding plant the electron beam gun is bolted to the vacuum chamber (centre). The control desk in the rear carries all controls for the high voltage instruments and electron guns, the desk in the foreground contains the controls and gauges of the vacuum plant

★ 288

Boiling water research

rig facilities

Nuclear development work of AEG is supported by a number of experimental facilities that include an Argonaut type reactor, the PR10, that reached criticality on Janury 27, a heat transfer rig, a test rig to study crud formation and deposition, and another rig for performance checks on control rod drive mechanisms. For the study of steam-water separation, the test rig that has been in operation in Frankfurt is to be transferred to AEG's own nuclear laboratory. The heat transfer rig—420kW d.c. at 70V and 6000A—yielding a heat flux of the order of 400W/cm², is to be used for special measurements on two-phase flow such as steam slip, pressure loss and burn-out. ★ 289



KARLSRUHE'S CYCLOTRON. Ruhrstahl made this magnet for the AEG isochronous cyclotron that is now operating at the Karlsruhe nuclear research centre. In this accelerator, in order to keep the revolution time of particles constant on every orbit, magnetic induction has been increased to compensate the relativistic increment of particle mass

★ 290

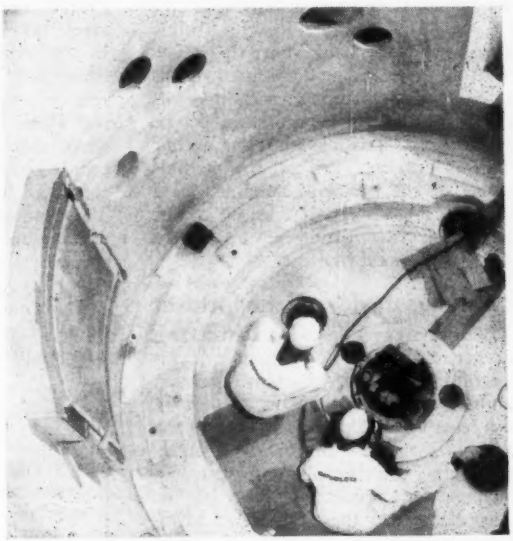
MOBILE RADIATION LABORATORY Frieseke & Hoepfner's VW-bus fitted with FH53 radiation monitor, type 49 scaler and ratemeter, type 51 flow counter with windowless FH514 proportional counter, FH451 scintillation counter with Z11 well-type crystal, FH422 dust sampler and type 509 water evaporator. The standard vehicle, equipped as above, is well suited for the continuous measuring and recording of dosage rate of ambient radiation (with the car either in motion or stationary); discontinuous measurement of radioactivity level in air and water; and the discontinuous measurement of granulated and liquid radioactive samples. By using GM tubes as supplementary equipment, β and γ radiation can be measured in places difficult of access or in heavily contaminated liquids within an area of up to 330ft around the car; or substances emitting α, β and γ radiation can be localized. The compartment in the rear over the car's motor is separated from the main compartment by a gas tight wall and it contains two miniature generating sets driven by a two-stroke engine. In addition there is a methane cylinder, a 20-litre water container and a roll of 160 ft mains cable. Mounted on the top of the car is an ion chamber

★ 291

Building the FR2

The main construction work for Karlsruhe's 15MWt heavy water research reactor, expected to go critical late this year, is being done by Dingler. The reactor vessel is a thin-wall circular cylinder shell of welded construction—124 ft dia, 92 ft high—and it carries 177 tons from a circumferential craneway without perpendicular bracing

▲ Base plate forming the lower part of the biological shield before the concrete stage



▲ Inside the reactor vessel-showing the base carrying the central loop tube and the D_2O inlet and outlet ports; and the experimental ports in the wall

The FR2 building nearing completion ▼

▲ Siemens designed and constructed the control room and instrument panels

★ 292

★ *For further information on any item, circle the appropriate number on the reply card facing page 122.*

Information obtained in the 13 days after the SL-1 accident indicated that the probable cause was a nuclear excursion resulting from motion of the central control rod

Members of the US Army's Chemistry Radiological Unit, in special anti-contamination clothing, respond to an emergency call for entry into the SL-1 Reactor Building

Interim report on SL-1 accident

THE SL-1 reactor accident at the USAEC's National Reactor Testing Station, Idaho, could have happened with no errors being committed by the three man crew though certain errors on the part of the operators can also be visualized as possible initiating events. This is one comment on the possible cause of the accident contained in a 15 page interim report released by the Board of Investigation set up by the USAEC General Manager.

Conditions prior to the incident

The report says that when the accident occurred, the shift supervisor, his operator-mechanic assistant and an apprentice-trainee were on the top of the reactor, presumably engaged in the various manipulations involved in re-assembling the control-rod drive mechanisms and connecting four of the control rods to their respective mechanisms.

For the reactor to achieve its intended purpose, it was necessary to load the core initially with sufficient excess fuel so that it could still be operative after three years use. To counterbalance the excess reactivity of this heavy fuel loading, poison material—boron—having a reactivity value of 11%, was also added to the core. It was intended that this poison would burn out at about the same rate as the excess fuel was consumed. Five cruciform-shaped control rods—one central and four outer rods—were provided, having a reactivity value of about 14%. Each blade of the control rod structure consisted of a sheet of cadmium, 7 in wide, 34 in long, and 0·06 in thick, sandwiched between, but not bonded to, two plates of an aluminium envelope. The edges of the aluminium envelopes were welded but it was believed that the welding might not be impervious to water. Hence the top centre of the envelope was left unwelded to permit the escape of steam and thus forestall pressure buildup inside. The central shut-down margin was intended to be about 3½%–4%. (Values are for ambient temperature, zero power condition.) According to the design, complete removal of three outer rods would not make the reactor critical. Removal of the central rod alone a distance of 19 in would make the reactor just critical; further, rapid removal above 19 in would cause a serious nuclear excursion. The motor drive for this rod was geared during operation to permit a maximum speed of 1·8 in/min to preclude rapid removal.

Along one side, and sometimes on two sides, of each fuel element of 4 in² cross-section, a strip of Al-B—10(0·4%)-Ni alloy was attached as burnable poison. As a result of the extrusion process of fabrication, there was a thin (1·5-2 mils) coating of aluminium on the Al-B—10-Ni alloy. The strip was spot welded to the side plates of the fuel element at approximately 3 in intervals. Some 40 full-length and 16 half-length strips accounted for 11% reactivity. These boron strips were more heavily loaded toward the centre of the core and in the bottom half of the core.

Difficulties with boron strips

Early in the reactor's life it was noted that the boron strips were beginning to

SUMMARY OF FINDINGS

1. The explosion occurred in the SL-1 reactor at approximately 9.00 pm on January 3, 1961, resulting in the death of three persons, in damage to the reactor and to the reactor room and in high radiation levels (approximately 500-1000 r/h) still present within the reactor room.
2. Two members of the crew were killed instantly by the explosion. The third died within about two hours as a result of an injury to the head.
3. The SL-1 explosion involved a nuclear reaction. The thermal nvt above the reactor is currently estimated to have been approximately 10^{19}/cm².
4. Chemical and radioactivity measurements on a single fragment of reactor fuel ejected by the explosion, if representative of the total fuel, suggest that the reaction may have resulted in $1{\cdot}5 \times 10^{18}$ fissions.
5. At the time of the explosion, the reactor crew appears to have been engaged in the reassembly of control rod mechanisms and housings on top of the reactor. The pressure generated within the reactor, which may have reached several hundred lb/in², was vented through a number of partially closed nozzles in the head of the reactor, blowing out shield plugs, portions of control rods and some fuel.
6. The explosive blast was generally upward from the ports in the top of the reactor. Structural damage to the building, principally due to objects projected from the nozzles, was slight. Damage to the core cannot be determined at this time.
7. Some gaseous fission products, including radioactive iodine, escaped to the atmosphere outside the building and were carried downward in a narrow plume. Particulate fission material was largely confined to the reactor building, with slight radioactivity in the immediate vicinity.
8. At this time, it is not possible to identify completely or with certainty the causes of the incident. The most likely immediate cause of the explosion appears to have been a nuclear excursion resulting from motion of the central control rod. As yet there is not evidence to support any of several conceivable initiating mechanisms.
9. It is known that a variety of conditions had developed in the reactor, some having their origin in the design of the reactor and others in the cumulative effects of reactor operation, which may have contributed to the cause and extent of the incident.

CASE HISTORY

The SL-1 (originally known as the Argonne Low Power Reactor) was designed and test-operated by the Argonne National Laboratory. Pioneer Service and Engineering Co. was architect-engineer, and the construction was performed by Fegles Construction Co. The SL-1 achieved criticality on August 11, 1958, with ten fuel elements containing a total of 3·5 kilograms of U-235. There followed a series of critical experiments, performed in the reactor, to determine the fuel and burnable-poison loading necessary to insure 3-MWt capability at the end of three years of operation at 70% load factor. Those design objectives were met by using 40 fuel elements, 40 full-length and 16 half-length boron strips, and five control rods. Critical experiments were also performed on a full 59-element core that would have higher power capability. The differential and integral worths of banks of five and nine control rods were obtained as a function of rod insertion into the core. Flux plots were made of the hot 40- and 59- element cores by irradiating gold and copper wires, respectively. On October 24, 1958, the SL-1 achieved its full-power output of electricity and space heat.

Sequence of Events

After slightly more than two years operation, the SL-1 was shut down on December 23, 1960 for maintenance on certain components; the only work planned for the reactor core was the insertion of 40 cobalt flux measuring assemblies into fuel element channels of one quadrant of the core. Access to the core through nozzles in the head of the reactor vessel required removal of the control rod drive assemblies. This portion of the work was begun during the early morning hours of January 3, 1961. When the day crew arrived at the SL-1 on January 3, disassembly had been completed. Installation of the flux measuring assemblies was accomplished during the day shift.

The crew of the next shift (4:00 p.m. to midnight, January 3) consisted of three military personnel: a chief operator, and operator and a trainee. This crew and the following one were assigned the task of reassembling the control rod drives and preparing the reactor for startup.

At approximately 9:00 p.m. on January 3, alarms indicating a possible fire at the SL-1 sounded at the Central Facilities Fire Station, the AEC Security Station, and other fire stations within the National Reactor Testing Station. Upon approaching the SL-1 the fire and security personnel observed no indication of a fire or other damage. Upon entering the SL-1 fenced area, the fire department personnel were unable to arouse the SL-1 crew. The assistant fire department chief entered the reactor support building and immediately detected radiation levels up to 25 roentgens per hour (r/h). He could observe none of the SL-1 crew in the reactor support building. A health physicist from the Materials Testing Reactor-Engineering Test Reactor facility arrived shortly after. He entered the reactor support building and observed increasing radiation levels as he proceeded toward the reactor. He detected levels of 200 r/h at the stairway to the reactor and left to obtain further instructions.

Entry into the reactor room was later effected and two of the crew were found on that floor near the reactor in radiation fields of approximately 1000 r/h. One of these two crewmen was still living; the other, dead. Removal of the living man was accomplished by approximately 11:00 p.m. Shortly thereafter, he was pronounced dead.

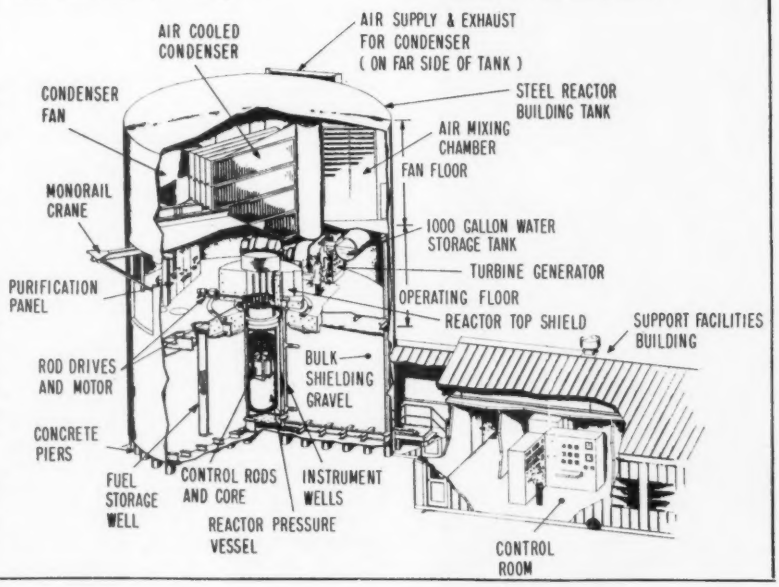
On subsequent entry into the reactor room, the body of the third crewman was located in the ceiling structure directly over the reactor. Because of the high radiation levels, it was not possible to remove the second crewman until January 5, and the third crewman until January 9.

The Evidence

Indications that a nuclear excursion took place were provided by the following: (a) Identification of the yttrium-91 isotope, resulting from the decay of the fission product, strontium-91, in a metallic sample shaken out of the clothes of one of the deceased; (b) Analysis of the activation of copper (to Cu-64) in a cigarette lighter screw; (c) Analysis of the activation of copper in a watch band buckle; (d) Analysis of the activation of gold in a finger ring worn by one of the deceased; (e) Analysis of the cobalt-58 activity induced in a gasket from the top of the reactor; (f) Analysis of the chromium-51 activity induced in a gasket from the top of the reactor; (g) Identification of gross fission products in air samples taken one and two days after the incident; (h) Response of monitoring instruments at nearby sites to the passage of a radioactive cloud; (i) Observations of radioiodine contamination of sage brush; and (j) Observed blast effects on components and personnel.

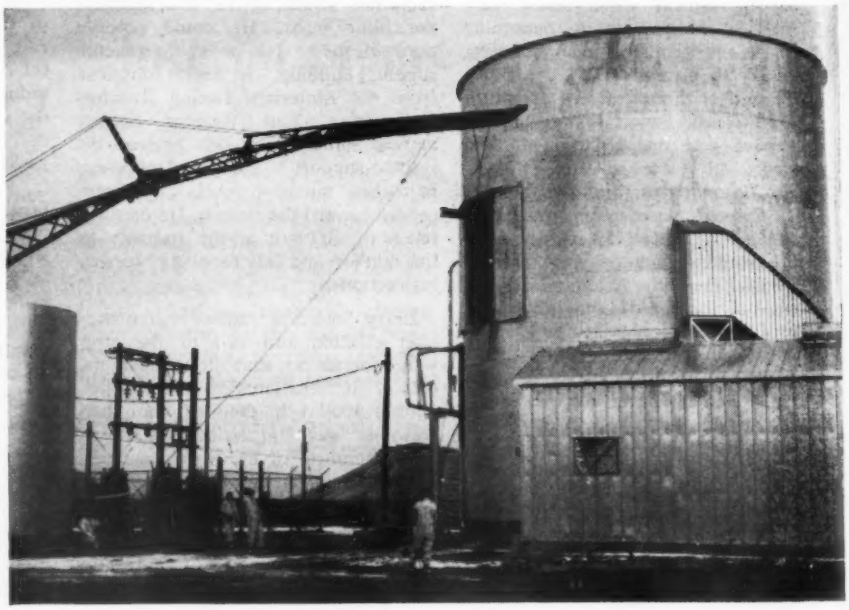
The Investigators

The special Board of Investigation consisted of Mr Curtis A. Nelson as Chairman and of the following members: Dr Clifford Beck, Dr Peter A. Morris, Dr Donald I. Walker and Dr Forrest Western. The Board was directed to investigate, and report to the General Manager on the SL-1 incident. The following persons served as consultants or advisers to the Board: Dr William Ergen, Mr E. B. Johnson, Dr Benjamin Lustman, Dr Warren Nyer, Mr. Howard K. Shapar and James H. Sterner, M.D.



The SL-1 is a direct cycle boiling water reactor of 3 MW gross heat capacity, with enriched uranium fuel clad in aluminium and moderated and cooled by light water in natural circulation. The reactor was operated as a prototype of a facility that could be operated at remote sites for three years without refuelling. It was designed to produce 200 kW of electricity and 400 kW of space heat

▲ Radiological safety crew members monitor a spot on the roadway leading to the SL-1 reactor complex, visible in the far background, for radioactivity



Four radiological safety crew members (foreground) guiding the placement of a 25 ft x 5 ft 'net' in preparation for the recovery of the last of the three victims of the January 3 accident. The reactor doors were breached and the net carefully moved through the open doorway and placed into position for the subsequent recovery of the body when it was dislodged from the second floor ceiling of the reactor room ▶

◀ This interior photograph of the reactor was taken on January 5. It was taken from a point near the top of the main access stairway looking along one side of the two reactor shielding blocks. The top of the reactor is on the other side of the blocks. Auxiliary equipment can be seen in the background, also an electric light still burning. The bell - shaped slender cylinders (centre) are control rod shield plug bell housings essentially as they stood awaiting installation before the accident. The ladder was knocked over in a post-accident effort

This photograph shows the pressure-vessel head of the SL-1 still in place. On the floor (foreground) are cylindrical steel punchings with some gravel and boric oxide which formed the dry-mixture shield above the reactor head. Still in place is a 41 in bell housing which encloses the No. 5 control rod shield plug. In front of the bell, lying on its side, is a control-rod extension shaft still fitted within its shield plug ▼

bow outward, away from the fuel plates, in the sections between the attachment weld points. This outward bowing increased steadily to a point where removal of elements in the central region of the core could be accomplished only with great difficulty. Concurrently, the reactivity of the reactor began to increase more rapidly than expected until in September, 1960, when a net gain of 2% over expected value had been observed. At this time three fuel elements were removed for inspection. Great force was needed to remove the elements and the boron strips remaining on the elements were damaged and shattered in the process.

It was estimated at the time that 18% of the boron had been lost from the core. When the core was disturbed, clouds of white flocculent material streamed into the water from the boron strips. After the reactor core had been reassembled, it was estimated that the shutdown margin was then only about 2% (the exact margin being uncertain.)

The shutdown margin was increased by the addition of six cadmium strips, each welded between two aluminium plates, into the unused T-shaped control rod shroud tubes (bottom ends open) on opposite edges of the core. These were inserted into position in November, 1960. The shutdown margin was increased by about 1%, less than expected, and the total shutdown margin was then estimated to be 3%. Positions of control rods at the final shutdown on December 23, 1960, indicated that just prior to shutdown, the margin had not changed.

Difficulties with control rods

From early operations onward, intermittent and increasing difficulty was encountered in the free movement of control rods. Over the first year of operations and possibly in large measure thereafter, the difficulty arose from the friction in the seals through which the drive rod shafts penetrated the rack and pinion gear housings on top of the reactor. It was frequently found that one or another of the rods would not fall freely when the magnetic clutch drive was disconnected in a scram or single rod drop test. Later the sticking problem became accentuated.

Evidence suggests the control rod shrouds may have been compressed by the expanding boron strips so that rod movement within the shrouds was impeded. Over the last two months of operation, approximately 40 rod stickings were recorded in the Operations Log. During the last period of reactor operation, the rods were assisted manually in their withdrawal and on scram at shutdown, three rods had to be driven in by their motors.

The reactor was operated at 3 MWt up to November, 1960. At this time, to test a new condenser loop of higher capacity, approval was given to operate the reactor at 4·7 MWt. Over the period to December 23, the reactor was operated for a dozen short runs at 4·7 MWt. The effects of this increased power level were an increase of about five degrees in operating water temperature, some increase in radiation levels and some increase in turbulence in the core. It was found the reactor could not be operated at this level with the usual control rod pattern (all rods equally out) without 'chugging' instability. Hence, operation at 4·7 MWt was accomplished with the outer four rods almost fully withdrawn and the centre one in as far as necessary. This pattern achieved some flux-flattening, and was made necessary, at least in part, by the loss of boron from the central region.

Reactor damage

No 'meaningful' information is available as to whether or not the reactor vessel itself had been damaged (except for the top of the vessel.) Preliminary estimates have been made of an internal pressure as great as 500 lb/in², from observed damage to the top of the reactor vessel and from calculation of energy needed to propel certain components to observed locations. The sheet-metal covering on top of the reactor head was bent upward—allowing dispersal of some of the gravel, steel punchings and pelletized boron shielding material. Shield plugs and other parts of the control drive mechanisms, which had been placed in the reactor nozzles, were blown upward by steam or water pressure. Control Rod No. 5 which had not been disassembled, appeared to be intact and in place. The racks on the top ends of two control rods extensions have been observed to be protruding from the nozzles for control rods Nos. 1 and 7—indicating that these two control rods may still be in the core. Another control rod extension has been observed to be lying across the top of the reactor though the location of the associated control rod is unknown. The location of the remaining control rod is also unknown.

One estimate of the nuclear energy release places the total fissions during the excursion at $1{\cdot}5 \times 10^{18}$—equivalent to 50 MW sec. It is believed that an energy release significantly less than this would not have produced the observed blast effects and that an energy release greater by a factor of 3 or 4 would have produced much more drastic effects.

Possible causes

The tasks assigned to the operators (reassembly of control rod drives) involved the lifting of the control blade a maximum of 4 in. Testimony indicated that the Chief Operator and the Operator had performed this same task at least four times before the occasion in question and had been specifically trained for this job. Their training included the explicit instruction that under no conditions was the central control rod to be lifted more than 4 in. From the positions of the men after the incident and the injuries they suffered, 'we are unable to rule out the possibility that one of them was engaged in lifting the central rod at the time of the blast. At this time, however, there is no direct evidence.'

From measurements made prior to the reactor shutdown on December 23, it would have been necessary to raise the central control rod a minimum of 16 in at that time to produce criticality. On the basis of existing information on the reactivity worth of the central control rod (prior to shutdown) and the results of BORAX and SPERT experiments, it is estimated that this rod would need to be withdrawn another 6 to 8 in at a rate of approximately 24 in/sec to produce a nuclear excursion of the magnitude estimated to have occurred. While these actions and conditions appear credible, they do not appear probable in the light of the preliminary evidence thus far available.

Another set of circumstances 'involves the possibility that some changes occurred in the properties of the reactor between December 23 and January 3—changes which would minimize the capability of the control rod system to maintain the reactor shutdown. There is no evidence at present that any such changes took place. If loss of cadmium or loss of boron occurred during the shutdown period in question, the shutdown margin of reactivity would be reduced. With a reduced shutdown margin of reactivity, substantially less withdrawal of the central control rod would have produced criticality.'

The report adds that other conceivable initiating events, though at present their likelihood appeared low, included: (a) a water-metal, hydrogen explosion, or other chemical reaction which would drive out the central rod or several of the rods from below or by a general pressure increase. (b) addition of water to a core which had become dry and otherwise changed.

'It should be emphasized that the foregoing discussion is limited to possibilities and is not intended to imply any degree of probability. It appears now that the most likely immediate cause involved some movement of the central control rod', the report states.

The development of complex laboratory equipment is necessary for a successful irradiation programme

Irradiation techniques for fissile materials—3

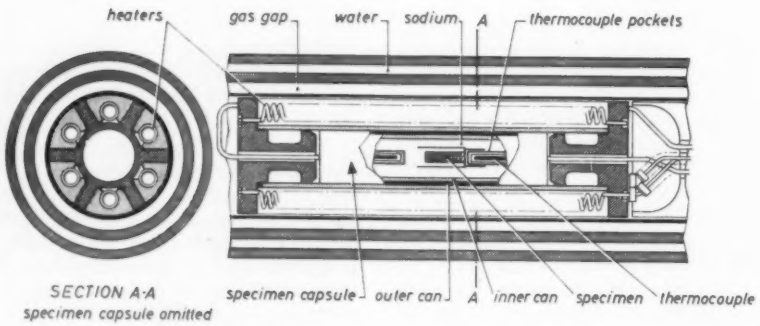
by O. S. PLAIL, A.M.I.Mech.E., Group Leader, Irradiation Branch, Metallurgy Division, AERE, Harwell

ALTHOUGH PREVIOUS ARTICLES in this series have traced the development of in-pile rigs for fissile irradiations, little reference has so far been made to the techniques used for the containment of fissile materials, heater development, temperature measurement, instrumentation, rig safety, out-of-pile testing, and laboratory simulation work. All of these are important aspects of an irradiation programme of the type under discussion; they are necessarily intimately connected but it is convenient to discuss them individually, and the first two are discussed in this article.

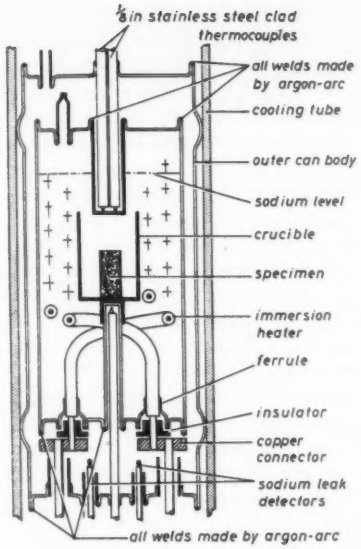
DEVELOPMENT OF CANNING TECHNIQUE

The basic canning technique for the irradiation of small fissile specimens (i.e. double stainless steel cans, molten sodium for heat transfer, a zirconium barrier to prevent alloying of the specimen with the can) had already been worked out for the early Windscale experiments; it was therefore reasonable that the first cans used in DIDO should be almost identical to those of the earlier work. Figure 1 illustrates this, showing the sodium filled inner can shrink-fitted into the outer one which is, in turn, fitted tightly into the zirconium former carrying the furnace. Outside this furnace was the gas gap thermal barrier described in the previous article. This arrangement had serious disadvantages. Firstly additional thermal barriers could exist due to the variations in fitting the can components together. Secondly, the can dimensions limited the size and number of specimens that could be accommodated. Thirdly the furnace construction and assembly was difficult. A completely new can design was therefore produced (Fig. 2). The size was increased considerably although double canning was retained; this allowed several specimens to be grouped together in the same can in the central zirconium crucible. To cover the experimental temperature range, i.e. 200–800°C, a series of cans of various diameters was needed so that the gas gaps which fixed the can temperature could be selected.

To reduce neutron losses, the wall thickness of the cans was reduced to a minimum; the inner can was 0·020 in thick and the outer can 0·010 in. Although this involved machining difficulties, these were considered outweighed by the advant-



Capsules used for early Dido irradiation; these are almost identical to those used in the earlier Windscale work. (Fig. 1)



First immersion heater capsule Dido (Fig. 2)

ages in reduction of enrichment, etc. The possibility of inner can failure due to internal pressure was guarded against by careful control of the quantity of sodium, the provision of adequate expansion space for the molten metal and the introduction of helium at reduced pressure so that at the operational temperature the internal pressure would approximately balance that applied externally by the rig atmosphere; thus the canning system was virtually stressless.

A novel feature of this capsule design was the provision of an immersion heater in place of the earlier furnace; this, with the thermocouples, entered the capsule assembly from the bottom end cap. The welding in of these thermocouples and the heater was very difficult and quite early on in the use of this design, sodium leaks occurred at the bottom of the inner can. At least one such leak was traced to a faulty weld and in an attempt to prevent further failures the already tight inspection procedure was made even more stringent by the introduction of a long term life test on the completed sodium filled capsule. At the same time the design of the capsule was modified so that the heater and thermocouples entered via the top end cap thus reducing the total number of welds and the number in contact with molten sodium. This however increased the probability of hot spot formation in the heater in the expansion void above the sodium, and to overcome this a heater with thick ends was designed.

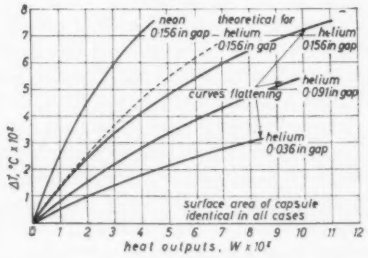
Although the preliminary work had shown that gas gaps could be used effectively little was known in detail regarding their behaviour and therefore parallel to these canning developments a systematic investigation was carried out to study their characteristics. Laboratory experiments were performed to determine such things as dimensional stability, effects of varying quantities of gaseous impurities, heat losses using gases other than helium, end losses, convection effects etc. Typical results are shown in Fig. 3 compared with theoretical predictions based on published data. The results show that in many cases, end losses are fairly high—up to 20%—but rather surprisingly gaps of the order of 0.010 in are stable and distortion of the cans does not appear to seriously affect results. As would be expected from theoretical predictions convection effects are small below gap dimensions of 0.050–0.060 in. To take advantage of this the gap is divided into two small parts, one being located between the water jacket and the outer can, which is operated at a temperature above the melting point of sodium. This allows the molten metal to reach the leak detectors in case of inner can failure. The outer can is thus used as a sodium catchpot, and unlike the Windscale outer can does not provide secondary containment of fission products, these being retained by the rig envelope.

To improve further the canning procedure, the need for a variety of cans of differing diameters has been eliminated by introducing an aluminium sleeve between standard sizes of inner and outer cans. By altering the thickness of this sleeve the gas gap may be varied and the thermal constants of the system altered readily at any stage during capsule assembly. Also, by rearranging the various components, the thermocouple pocket can be positioned in the middle of the samples, thus considerably increasing the reliability of temperature measurement. These improvements are illustrated in Fig. 4 which shows the latest type of capsule assembly used for experiments in DIDO. For experiments in PLUTO, using larger specimens, operating at considerably higher heat outputs the canning arrangements are similar although the disposition of the thermocouples and heaters different.

HEATER DEVELOPMENT

Heater development has posed some of the most serious problems associated with all types of irradiation experiments. Although at the moment it would appear that for the fissile work at least, the troubles have been solved, this has taken several years of concentrated effort. For a heater to work well in-pile there are several general requirements. It must be mechanically robust, be reliable for long periods, have adequate heat output to maintain temperature during reactor shutdown conditions if required, and it should not suffer from irradiation effects. In addition, the heater ends should be designed so that strong and reliable connections between heater and power cables can be made.

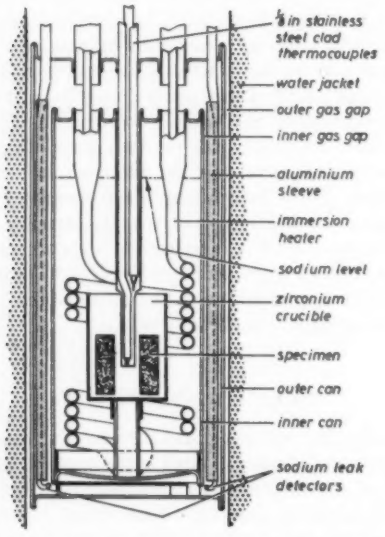
For the earlier DIDO experiments the heater illustrated in Fig. 1 was used. It consisted of a zirconium former with ceramic inserts carrying heater windings of 80/20 Ni/Cr alloy. Both laboratory tests and in-pile experience showed this to be most reliable and capable of at least twice its design rating at high temperatures. However as well as limiting the can size that could be accommodated, this heater was expensive to produce and, because the zirconium had to be hafnium free to avoid serious neutron losses, supply difficulties were


neon 0·156 in gap
theoretical for helium 0·156 in gap
helium 0·156 in gap
helium 0·091 in gap
curves flattening
helium 0·036 in gap
surface area of capsule identical in all cases
ΔT, °C x 10²
heat outputs, W x 10²
0 1 2 3 4 5 6 7 8 9 10 11 12
1 2 3 4 5 6 7 8

Results from typical gas gap experiments using sodium-filled capsule identical to irradiation capsules (Fig. 3)

experienced. In addition due to the large thermal capacity its response to temperature changes was slow. The design was therefore abandoned although a modified form is currently being investigated.

As stated above, an immersion heater was used with the new capsule design and its introduction was a big advance. It has the advantage of low cost, compact design and, when used in a high heat transfer medium such as molten sodium, the ability to dissipate very high heat outputs. In-pile experience has shown that excellent temperature control is possible



Latest immersion heater capsule for Dido (Fig. 4)

with these immersion heaters and under steady reactor conditions ±0·5°C is normally achieved. It is worth noting that considerable attention is being paid to this type of heater in the USA.

When the design of the new can was produced, no suitable immersion heater was available commercially and in designing one the following additional points had to be satisfied. Firstly it was considered desirable to limit the heater element to 1000°C. This is a very conservative figure for heater element materials. Secondly the heaters had to fit into the inner can without imposing serious limitations on the available space for the specimens. Thirdly they had to be resistant to sodium attack and finally capable of being sealed into the capsule.

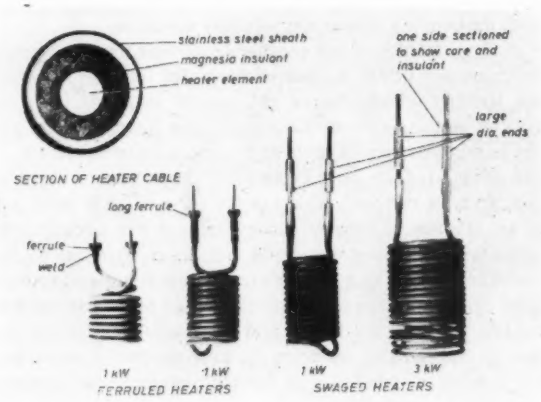
Various designs including fabricated tubular heaters were considered but the choice rested on stainless steel clad mineral insulated (MgO) cable whose core was 80/20 Ni/Cr. Figure 5 illustrates the cross section of this cable together with typical coils. Conservative data for the thermal conductivity of MgO was used when designing the cable so that should cracking or sintering take place, the core temperature limit of 1000°C would not be exceeded. It now appears that the thermal gradients in the MgO are considerably less than at first anticipated.

Tests on the first batch of cable showed it to be robust and capable of high heat transfer rates; 60 W/in. (twice that required) was achieved. Subsequent tests at 800°C have given rates approximately double this value without burn-out. Sealing into the capsule was tackled by welding to the heaters small ferrules which were then edge welded into the end caps (see Fig. 5). However, both gas and argon-arc welding failed to give satisfactory joints, and failure of one of these welds caused a sodium leak leading to the capsule re-design and the introduction of top entry heaters.

The new heater designed to avoid hot spot formation above the sodium with ends of larger cross-section than the actual coil is shown sectioned in Fig. 5. Introduction of these also eased the problem of end connections. Of the several manufacturing methods considered for these heaters rotary swaging from large diameter cable seemed likely to yield results. Early swaging attempts led to cracking and uneven reduction of both the sheath and core but careful attention to inter-pass annealing and die design overcame these troubles and it is now a standard method of production. Fabrication using either welded or brazed ends was investigated. Welding reintroduced some of the weaknesses that the heater was designed to eliminate and suitable sodium resistant brazes were not then available.

As an interim measure during these developments modifications to the ferruled heaters were introduced (see Fig. 5). It will be seen that a long ferrule which reached into the molten sodium was used to suppress hot spot formation by providing a greater heat transfer path.

During the course of this development work an interesting electrical phenomenon was noted. It was found that MgO used in the cable gave very poor electrical resistance at moderately high temperatures (500–600°C) resulting in the failure of several heaters during laboratory testing. From published data it would not be expected that the electrical



Various types of immersion heaters for capsule irradiation (Fig. 5)

resistance of MgO would drop seriously until much higher temperatures were reached (~1000°C). This phenomenon, which is temperature-voltage dependent, has also been observed by others, is unpredictable and variable from batch to batch of apparently similar material. Although grades of MgO are available which do not suffer from this effect, the mechanism is not yet clearly understood.

Resulting from this development a swaging process has been worked out which coupled with good quality MgO insulation, is capable of providing reliable heaters for in-pile use. In addition it should be possible with sodium resistant brazes now available to fabricate heaters of almost any shape and size for these irradiation experiments.

BUSINESS NEWS

LOWER PROFITS FOR GEC Provisional results for the first eight months trading and estimated figures for the remainder of the current financial year indicate that the profit for the year will be somewhat lower than last year, says the GEC. This is mainly due to reduced trading in the Radio and Domestic Equipment Groups. Trading in other groups has been maintained. Changes have been made in the company's administrative structure and further steps to strengthen the management are planned. (See *People*, this issue.)

To avoid major disturbances in production and trading, these changes will take place progressively, says the GEC. Time and concentrated effort are required to make them effective and it is expected that benefit will begin to appear in the coming year.

BETATRON FOR HEAD WRIGHTSON **Pantak Ltd** have received an order for an 18 MeV Siemens Betatron from **Head Wrightson (Teesdale) Ltd.** This mobile particle accelerator will operate in the heavy fabrication shop at Thornaby-on-Tees and will examine welds on the 4 in thick walled heat exchangers for the Dungeness nuclear power station. Pantak say the unit will require less radiation safeguards than those which must be adopted for other particle accelerators and high power sources.

NEW UK COMPANY A new company —**Shawford Control Gear Ltd**—has been formed to import into the UK from Italy, the CEMA range of heavy duty control units, solenoids, micro-switches and other products. First supplies have been available since February and additions to the range are to be introduced. The firm is situated in Willesden, London, NW10.

AEA DEVELOPMENT CONTRACT A development contract worth more than £20,000 has been placed with **Cawkell Research and Electronics,** a subsidiary of **Simms Motor and Electronics Corporation,** by the UKAEA. Under this, Cawkell will undertake investigation of new and more accurate methods of recording waveforms than previously obtained with oscilloscopes supplied for the ZETA project.

UNITED POWER COMPANY It has now been officially confirmed that the **GEC/Simon Carves Atomic Energy Co. Ltd** and **Atomic Power Constructions Ltd** will have equal representation in the **United Power Company. Nuclear Civil Constructors** as well as **Crompton Parkinson Ltd,** (see February, p. 53). will not be taking part. The UPC will tender for Oldbury nuclear power station.

MILES ELECTRONICS ORDER **Miles Electronics Ltd,** who supplied a MARC special purpose computer for the **Society for the Promotion of Nuclear Research** of North Rhine-Westphalia, have now supplied additional d.c. amplifiers and associated equipment so that the special purpose computer will be self-contained.

• **English Electric** has been awarded the contract for the design and manufacture of the main propulsion steam turbines and condensers for Britain's second nuclear submarine.

• **Furzehill Laboratories Ltd** of Watford have taken over the production, sales and service of the range of stroboscopes previously manufactured by **Watford Instruments** under the trade name Strobolyser.

• **General Radiological Ltd** have moved to County Building, Honeypot Lane, Stanmore, Middlesex.

• **Taylor Controls Ltd** have set up regional offices in Manchester and Birmingham capable of offering full sales engineering facilities to meet the company's expanding volume of business.

• **H & E Lintott Ltd** of Horsham has changed its name to **Lintott Engineering Ltd.**

• **Continental Distributors Ltd** are UK agents for **Alderson Research Laboratories,** Long Island, New York, who manufacture a range of radiological test phantoms.

OVERSEAS

VITRO-PECHINEY AGREEMENT **Vitro Corporation** of America has purchased all the minority interest in its chemical subsidiary **Vitro Chemical Company**—held by **Pechiney** of France. In addition to purchasing all stock and notes held by Pechiney, Vitro has entered into a new royalty agreement which will run until December 31, 1974. This gives Vitro exclusive US and Canadian rights to all present and future Pechiney process and product patents involving rare earth chemicals, metals, alloys and related compounds. It also produces for a mutual exchange of know-how in the field between Vitro and Pechiney during the same period. Such products as thorium, scandium, yttrium, hafnium and zirconium compounds are also included.

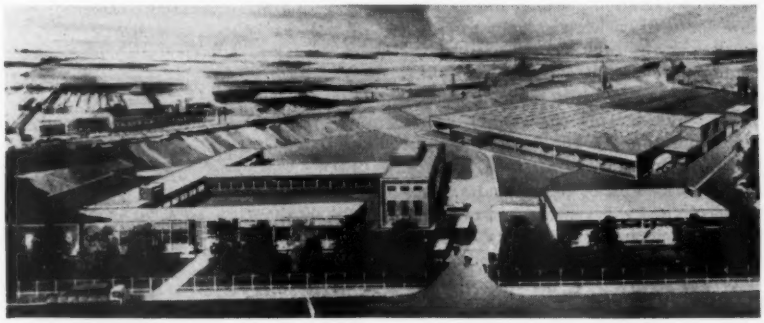
NEW EUROPEAN COMPANY A new French company to produce zirconium sponge and ingots, **Société Industrielle du Zirconium,** has been formed by three German, Italian and French groups. Each holds equal shares in the company. The German shareholders are **Degussa** and **Metallgesellschaft AG,** the Italian, the **Montecatini** group, while **Pechiney** is the leading French shareholder. The company, whose offices are at 195 faubourg Saint-Honoré, Paris 8, will also undertake research into the applications of zirconium sponge, especially in the field of nuclear reactors and chemical products.

FRENCH CAPITAL FOR SENA **Electricité de France,** by a decree published in the French Official Gazette, is empowered to contribute two million new francs to the capital of **Société d'Energie Nucléaire Franco-Belge des Ardennes** (SENA). This joint stock company, formed by EDF and the Belgian company **Centre et Sud,** is to build a 242 PWR on the Franco-Belgian border at Chooz. The contract for this is expected to be finalized with **Westinghouse** soon.

• **Radiation Materials Incorporated** has been formed by two New York firms, **Radiation Applications Incorporated** and **Loral Electronics Corporation,** to look into and develop the market for irradiated insulation products.

• **Isotope Specialities Co.** of Burbank has been acquired by **US Nuclear Corporation** from **Nuclear Corporation of America.** The sale was on a cash basis.

• **Texas Instruments Incorporated** of the US and **International Telephone and Telegraph Corporation** have agreed to exchange non-exclusive patent licenses and technical information on semi-conductor components.



SOLARTRON FACTORY. An artist's impression of the present offices, instrument servicing, training sections (left foreground) of the new premises of Solartron Laboratory Instruments Ltd at Chessington, Surrey. At right is the social centre and canteen

New Product Survey

EQUIPMENT · INSTRUMENTS · MATERIALS

This month's feature is devoted to a round-up of recent equipment from West Germany

REMOTE VIEWING

Used by the CEA and at Würzburg University's 35 MeV betatron, **Grundig's** Tele-Eye system consists of a pick-up camera, a modulator unit and a control panel. The camera is fitted to take a variety of lenses and a special tripod with fitted pan head allows the remote control of horizontal and/or vertical movements; the maximum cable length is 550 yd. A miniature pick-up camera is also available, $2^{9}/_{32}$ in in dia. and $5^{21}/_{32}$ in in length (without lens), that can be used in areas of limited space such as pipes.

Hensoldt have a range of periscopes for either areas of low level activity or for use in hot cells. The simpler version, with a length about 39 in, has an optical field of 60° and an angle of vision of 110°, by use of an adjustable mirror. Other equipment with one or more elbows can be supplied with a diameter of 6 in and a length of about 33 ft. Optical elements that are subjected to radiation are made of cerium oxide stabilized glass to reduced discoloration.

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NUCLEONIC EQUIQMENT

For over ten years **Frieseke & Hoepfner** have developed and produced both nucleonic apparatus and installations for the continuous measurement of weight and thickness, coatings, strip materials, liquid densities and for quality control. In the very large range of scalers, ratemeters, detectors and monitors currently available is the self-contained FHK3/485A counter designed to simultaneously count impulses from a connected radiation detector and measure time—both of which can be preselected. Another new ratemeter, FHK3/518, shows the impulse rate as a measured value, it is fed to a built-in potentiometric recorder to produce a trace. Time changes are thereby shown in the impulse rate. Impulse analyser FH507, a linear amplifier with a single channel discriminator for X- and gamma-ray spectrometry, has an input resistance of 6·4kohm and an input capacity of about 30pF. Channel height is continuously adjustable from 2-52V, the channel width likewise, in two ranges 0/5 and 0/50V, i.e. over the whole spectrum. Using the FH516 automatic sample changer, connected to two 90 scalers, 902 control units and two printing timers, 30 samples can be measured either for alpha and beta separately or for alpha-beta and gamma.

A wide range of radiation equipment is also produced by **Berthold.** Among the latest counters is the TOL/C dose ratemeter that uses a plastic counter tube for measuring X-, beta- and gamma-rays between the range 0 and 100mr/h, and the thin-walled G.M. counter, BZ120A, designed for air and water monitoring. The standard type hand and foot monitor has now been improved by becoming fully transistorized. Also for the continuous control of air and water contamination is radiation monitor MON/C that, coupled with G.M. counters or scintillation counters, has seven different ranges between 5 and 500c/s; with the time constant adjustable in five steps: 10, 60, 120, 300 and 600 sec.

A differential amplifier version of a reactor period meter is being marketed by **Kirem** for Hartmann and Braun that has a null point drift of 0·5% per week. In the built-in indicator type, power is held constant electronically. Among the various firms making pocket dosimeters is **Physikalisch-Technische** whose latest model is an acoustical warning type.

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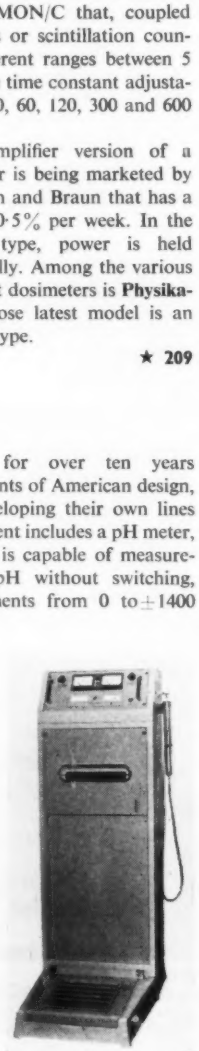
ANALYSIS

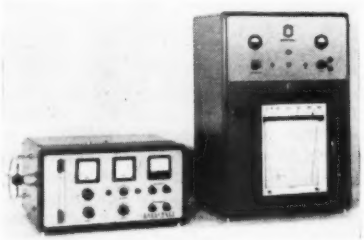
Having supplied for over ten years laboratory instruments of American design, **Virus** are now developing their own lines and current equipment includes a pH meter, the Pehamult, that is capable of measurements from 0–14 pH without switching, and mV measurements from 0 to ±1400 mV. It uses a two-step direct voltage amplifier with strong counter coupling. Their Gasofract 300, a universal instrument for the analysis of gases and liquids, operates over the range 25–300°C and permits the plots of both curves of registered values and their integrals to be made in one operation.



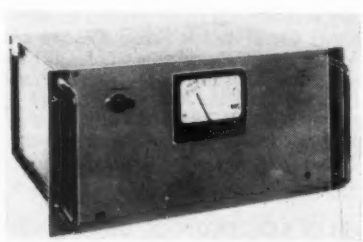
Hand and foot monitor—Berthold

Count rate meter X500—Graetz

In the field of mass spectrometers, **Atlas-Werke** have modified their medium sized instrument, the M86 and the redesigned gas inlet system and ion source now gives greater versatility. Pressure vessels and other systems can be tested with full sensitivity with a pressure inferior to 5×10^{-8} mmHg. Leak detection is also possible if only a forepump and no diffusion pump is available. The latest instrument, the PSH65, is an electrical quadrupolar instrument with a working range of from M=12 to M=65 and a resolution mass difference of M=1. Suitable for temperatures up to 300°C it is particularly suited for partial pressure measurements in high and ultra-high vacuum systems.



Gasofract 300—Virus



Reactor period meter, VEP—Kirem

An interesting new series of measuring instruments from **Gossen** are the Pantam measuring relays and regulators for the automatic control of temperature, pressure, level, frequency, current and voltage. **Phywe**, suppliers of laboratory furniture, laboratory apparatus and radiation sources now have available a variety of relatively simple nucleonic and electronic instruments that can be made up into different assemblies for basic physics experiments.

★ 210

VACUUM PLANT

Well known for their position in the vacuum plant field, and recently associated with Elliotts in the UK, **E. Leybold's Nachfolger** have among their latest equipment a compact gas ballast pump D25 that gives a displacement of 1·5 gal at atmospheric pressure and 5×10^{-2}mmHg ultimate pressure with gas ballast. For use on equipment where a pressure of about 10^{-6}mmHg is adequate, is the DO-30 air-cooled oil diffusion pump with dimensions: height 10·23 in, largest radius (including fan) 6·7 in. New in gas ionization gauges are type III with a measuring range extending from 10^{-3} mmHg to several times 10^{-7}mmHg, and type IV where the amplification factor of the measuring amplifier and the emission current of the measuring tube can be regulated separately. An interesting development is the Farvitron partial pressure indicator designed to establish the causes of pressure variations in a high vacuum system. A spectrum of the gases present in the system is constantly projected on the screen of the oscillograph tube.

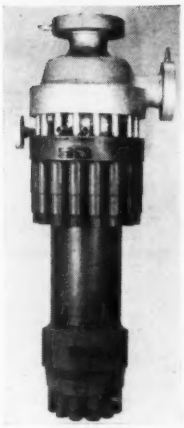
★ 211

PUMPS AND VALVES

For circulating relatively small volumes of coolant at high pressure, **Walbersdorf** have developed a three-cylinder piston pump with valve housing and cylinder connected only by means of bow-shaped pipes. Cooling jackets keep the circulating liquid to 20–30° above ambient, and thus prevent deterioration of seals and mechanisms by excess temperature. Another advantage is that low temperature packing materials can be used. By building the safety valve into the valve housing extra piping has been eliminated. One design is for an output pressure of 130 atm and an input pressure of 50 atm with an hourly throughput of 1122 gal at the mean temperature of 230°C. Another pump, under construction, will provide a pressure of 500 atm.

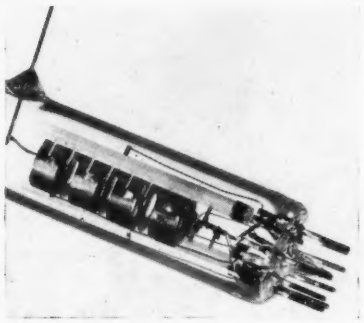
Hofer are also in the field of pumps for gases and liquids. They have three ranges of equipment for hot gases, all single or double acting: 2845, 4622 and 14,223 lb/in² with capacities of from 5·5 gal/h up to 6380 gal/h. A variety of fine adjustment valves in stainless steel are also available.

Sealed circulating pump—KSB

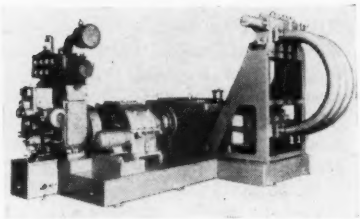


A range of hermetically sealed pumps available from **KSB** eliminate shaft seals and incorporate the pump and motor in one compact unit. The LUV series is suitable for high pressure hot water systems; the LUS series is intended for liquids where corrosion resistance is vital.

★ 212



Farvitron indicator tube—Leybold



Piston pump—Walbersdorf

IN BRIEF

• **Radiation sources.** Mainly for use in medicine, **Radium-Chemie** can supply a variety of sealed sources: strontium-90 in sealed plates for surface irradiation or in larger plates for ophthalmic use; cobalt-60, radium and caesium-137 in the form of cylinders, needles and plaques; tantalum-182 in wire form and iridium-192 and thulium-170.

★ 213

• **Remote handling.** Latest in tongs from **Buchler** is the detachable head and ball-joint type, that has an arm thickness of about ½ in and a length of over 28 in. They are also supplying curved lead screens supported on round base plates—lead thickness 2 in, width 24 in—with a floor coverage of 51 in by 7½ in. The screen weighs 441 lb and the floor slab 485 lb. Another firm supplying lead shield blocks, a variety of handling equipment and adaptable glove boxes, is **Hans Walischmiller.**

★ 214

• **Shielding materials.** The production programme of **Frank & Schulte** for heavy concrete shield constituents includes a granulated iron ore with a specific weight of 4·7-4·9, known as Magnetit beton. It has been used so far in the three German reactors: FR2, FRF and BER . Another material from, **Antitron,** makes concrete with densities ranging from 2·2 to 5·5. Two basic types are available: Antitron-R with a high proportion of elements with high atomic weights, for use with X- and gamma-rays up to 0·7MeV and over 10MeV, and Antitron-J for use in the range 0·7 to 10MeV. Designers of lead bricks and fuel element transport flasks, **Bleiwerk G. Rohr** can now provide rolled lead and lead sheets in widths up to 10 ft. and in unit weights up to 15432 lb.

★ 215

• **Computer accessories. Fernsteurergerate,** who are in the automatic process control field, have introduced an analogue/digital converter for flow and quantitative measurements.

The D1 fast digital printer that prints out decimal numbers on a paper strip, has been designed by **Kienzle** for connexion to electronic counters and allied equipment.

★ 216

• **Diesel engines.** Out of a wide range of air-cooled and water-cooled auxiliary power units, **Motoren-Werke Mannheim** have supplied the following variations of the type RHS518, water-cooled diesel to the German nuclear research centres: a smaller 58 hp version giving 40 kVA/kW and two 320 hp models of 250 kVA output.

★ 217

• **Neutron absorbers.** With a melting point of 2450°C compared with cadmium's 321°C, and only 40% of its weight, Tetrabor made by **Elektroschmelzwerk Kempten** is useful in such applications as marine reactors and movable screens. Consisting of 77-79% boron and 21-23% carbon, it can be supplied in grains; can be sintered into structural parts; is mixable with cement and can be bonded with aluminium and silicone rubber. Another control rod material—europium oxide, supplied by **Goldschmidt,** has a melting point of 2050°C.

★ 218

• **Gas filters.** With an efficiency of almost 100%, for dust particles coming within the critical range of 1 to 0·1 micrometre, **Delbag** have a range of dry-layer air filter packs varying in size from 9½ in × 9½ in to 2 ft × 2 ft, the equivalent air volume being 75 ft³/min to 1200 ft³/min respectively. The filtering medium consists of very fine thermoplastic filaments. For the extraction of radioactive wastes, **Seitz, Werke** have developed an almost fully automatic filter.

★ 219

★ *For further information on any item, circle the appropriate number on the reply card facing page 122.*

Cross Section by GRACCHUS

A TICKLISH problem not foreseen when the European Company for the Chemical Processing of Irradiated Fuels—Eurochemic, in short—was set up by 12 OEEC countries has now arisen. This concerns the method by which companies in some countries are taking part in the project. I am told the pattern is as follows:—a number of interested companies set up a separate company; this entity buys one share in Eurochemic from its government; the holding of this share entitles the company to participate in the project; the information it receives is passed on to the parent companies. This procedure is being repeated with sufficient frequency to cause concern in OEEC circles though exactly what can be done about it is difficult to see.

Of the 430 shares in Eurochemic, most are held by governments and semi-public bodies and only 20% by private undertakings. These shares can be transferred with the agreement of the General Assembly though I understand the General Assembly has little power to stop such a transfer.

IT WAS interesting to see in writing what one had heard in conversation about the difficulties with the pressure vessel for EDF–1. Some details of the way the crack in the pressure vessel was tackled were given by M. André Hannothiaux, general inspector, Electricité de France, at the annual conference of the Atomic Industrial Forum. 'Everything was going according to schedule until February 13, 1959,' he said. 'Up to that time, half of the vessel had been welded into place. That Friday, it was being cooled in order to make an X-ray examination of a weld when a crack 30 feet long suddenly appeared alongside a horizontal weld.

'Construction of the vessel was immediately halted to see whether or not the crack could be repaired, or if it would be better to start the vessel all over again. We studied at length information which had been gathered in the meantime concerning difficulties which had happened elsewhere for similar vessels, fabricated with steel of the same grade. (A team visited the UK).

'After six months study, it was finally decided to dismantle the vessel, stress relieve anew the plates and weld them again together according to a new and more elaborate procedure and under closer control. At present, we feel that we have mastered these difficulties but we are now more than 18 months behind schedule.'

AFTER MUCH shuttling between London and Johannesburg and talks behind the scenes lasting many months, new agreements on uranium have been signed between the South African Atomic Energy Board, the USAEC and the UKAEA. This provides for a 'stretch-out' of uranium deliveries, similar to that granted to the Canadians, and a fixed price for the metal supplied by South African producers.

One of the difficulties that faced the negotiators was the value to South Africa of its uranium export earnings. These totalled roughly £50 million a year and at a time when that country's foreign exchange reserves were falling, assumed greater importance. The new arrangement helps the country over this hurdle by lessening the impact on foreign earnings through the stretch-out; it also prepares the industry for the open market conditions that are expected in the next decade by rationalizing the South African uranium industry through the enforced transfer of production from high cost to low cost producers.

SOME HINT of the way the bid for the Chooz 242 MW PWR (SENA project) was selected has now come to light. A letter of intent was sent to Westinghouse-Framatome-ACEC in July last year awarding them the contract after bids by Indatom-Babcock & Wilcox and Alsthom-General Electric (BWR) had been considered. The Indatom bid was considered attractive but too expensive while the GE bid was considered practically equivalent to that by Westinghouse. The deciding factor was apparently that within Euratom, a BWR was being built (SENN) and an OMR (by AKS of Germany) was being studied and consequently it was worthwhile experimenting with another type of reactor. Bids were also evaluated on the amount of material to be made in Europe.

Incidentally, I hear that all has not been running too smoothly for this Franco-Belgian project. The problem of Belgian finance—once thought to be a formality—has still to be solved. Apparently the Congo crisis and the resulting internal difficulties have made it difficult to find Belgian capital for this European underground reactor.

I FELT I had to bring to your notice the following announcement published in the newsletter of the American Nuclear Society:

THE URRUTIA-BALL NUCLEAR CORP.
proudly announces the criticality
of Margery Lynn Urrutia
our Model *G2U
The First
'Organic Gas and Pressurized Water Cooled Reactor'

Date	9 November 1960
Time	18;00
Site	Mary Immaculate Hospital

*G—Its a girl; 2—Our second; U—Urrutia design.

REACTOR DATA

Power Output	10^{-6} MW
Fuel	100% enriched lactose
Cladding	Naturally enclosed
Weight	8 lbs 3 ozs
Coolant	Comb. Org. Gas and Pressurized Water
Noise level	500 decibels
Construction period	Record time of 8 mos. 3 wks

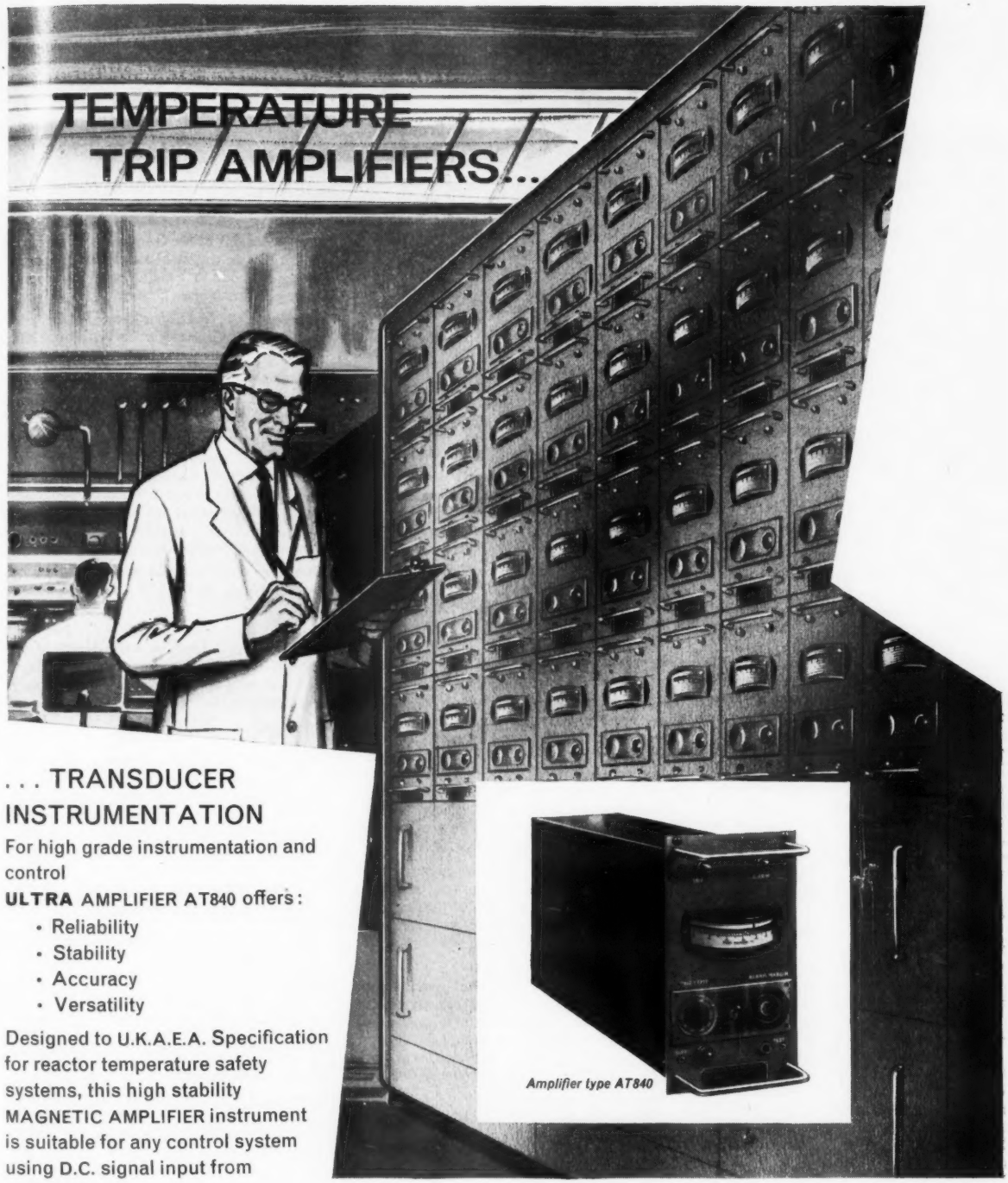
On Record

'Power from atomic stations is in the news. Too little is being produced to satisfy the public. An enquiry results in a reorganization and some large scale plans for new stations are modified.'

Old Moore's Almanac, 1961. Forecast for March.

'One of the most exciting developments in the fuel business in my opinion is the "coated particle" process . . . Irradiation of graphite matrix containing UO_2 coated with Al_2O_3 and with pyrolytic graphite has been carried out at quite high temperatures without any evidence of fission product release. If these data are confirmed, the possibilities for this type of element are almost unlimited.'

Dr Frank K. Pittman, Director, AEC Division of Reactor Development, before the Atomic Industrial Forum annual conference.



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STUDENTS' NOTEBOOK

BACKGROUND—Computers

How are digital computers programmed to solve reactor problems?

Excepting the devices for getting information in and out of the machine, a digital computer may be regarded as having two main parts: a means for holding information (the store), and the electronic switching arrangements for operating on data held in the store. An essential feature of modern machines is that the setting of these switches is controlled by information also held in the store. In addition to the data, therefore, one must supply a series of instructions (sometimes called 'orders') specifying the operations to be performed. This series of orders is usually referred to as a 'program'.

Computers do not (yet) understand English, so that the instructions must be in a coded form. The type of code varies from one computer to another, but all have instructions consisting of one or more 'addresses' giving the location of the numbers to be operated on, together with a 'function code' which indicates the operation to be performed. Thus in a numerical type code, the instruction 1 2 01 might mean 'Add the number in location 1 to that in location 2', with similar forms for subtraction, multiplication and so on. To be really useful, a digital computer must be able to change its path of calculation to suit the circumstances. This is achieved by a type of instruction usually referred to as a 'conditional jump'. For example 20 1 60 might mean 'If the number in location 1 is positive, carry straight on, but if it is negative, *jump* out of this sequence and obey the instruction in location 20 next,' thus initiating a different calculation sequence.

The more recent computers also have automatic coding schemes which allow instructions to be written in a form much more like mathematical equations; for instance $x_1 = y_1 + z_1$, which is self-explanatory. The jump order mentioned above might be written $\rightarrow 20,\ x_1 < 0$.

To show how such orders may be used, we will consider the calculation of a Bessel Function. Combinations of these arise very frequently in the solution of flux distribution problems and in lattice calculations. When doing these on a digital computer, it is usually quicker to calculate a Bessel Function each time it is required than it is to interpolate in a table of values held in the store. The I_o function is given to n terms by

$$I_o(x) = a_o + a_1 x^2 + a_2 x^4 + \ldots + a_n x^{2n}$$

We will rewrite this as

$$I_o(x) = 0 + \sum_{i=o}^{i=n} a_i x^{2i}$$

and keep in mind that $x^{2i+2} = x^{2i} \times x^2$. Our program might then look something like

$y_1 = 0$	[Clear location y_1]
$i = 0$	[Set index for first term]
$y_2 = 1$	[This is x^{2i} for $i = 0$]
$y_3 = x \times x$	[Form x^2 in location y_3]
1) $y_1 = y_1 + a_i \times y_2$	[Add $a_i x^{2i}$ to location y_1]
$y_2 = y_2 \times y_3$	[Form x^{2i+2} in location y_2]
$i = i + 1$	[Advance i]
$\rightarrow 1,\ i \leqslant n$	[Repeat from the instruction labelled 1) until $i > n$.]

The sum of the series will be found in location y_1.

Similar processes may be used to build up a program for the most complex or tedious calculation. Indeed, such things as the use of Monte Carlo methods for the accurate calculation of resonance escape probabilities, or the determination of flux distributions in awkward geometries by relaxation techniques, are only possible because of the high speeds attainable with recent computers. (Each might involve several man-centuries of hand calculation.) For other problems e.g. lattice calculations or thermodynamic cycles, extreme speed is not quite so necessary, but even a relatively slow digital computer can now do 0·5 to 1 man-years of work in an hour.

BOOKLIST—Computers

The literature on digital and analogue computers, and their techniques, is now very extensive. The following list excludes books concerned mainly with aspects of engineering and electronic circuitry, while works on numerical analysis that have no specific reference to automatic machinery are also omitted. Almost all the titles can be read by anyone with a pass degree.

Faster than Thought. B. V. Bowden. Pitman. 1953. Reviews the development of digital computers and includes an elementary account of machine logic and programming and a survey of machines working in the UK up to 1952.

The following books deal mainly with the logical design of digital machines and carry enough information on circuitry and hardware to demonstrate the working of the various processes. Most of them contain chapters on number representation and programming techniques.

Automatic Digital Computation. M. V. Wilkes. Methuen. 1956.

Digital Computer Principles. W. C. Irwin. Van Nostrand. 1960.

Digital Computer Fundamentals. T. C. Bartee. McGraw-Hill. 1960.

The books below which are concerned mainly with the principles and techniques of programming, also contain information on numerical analysis.

Preparation of Programs for an Electronic Digital Computer. M. V. Wilkes, D. J. Wheeler and S. Gill. Addison Wesley, 2nd edition, 1957. The first edition was the first book in the field and influenced most of the program work developed since.

Digital Computations. J. Jeenal. McGraw-Hill. 1959. A very detailed study of programming techniques covering the use of large scale equipment, at times using advanced mathematical methods.

Introduction to Automatic Digital Computers. R. P. Livesley. C.U.P. 1957. A very short and readable survey.

High speed Computing. S. A. Hollingdale. E.U.P. 1959.

Annual Review in Automatic Programming, vol. 1. Edited by R. Goodman. Pergamon. 1960. A wide review of automatic programming methods in general, and for several particular machines.

Automatic Digital Calculators. A. D. and K. H. V. Booth. Blackie. 2nd edition, 1956.

Numerical Methods for High Speed Computers. G. N. Lance. Iliffe. 1960.

Mathematical methods for Digital Computers. A. Ralston and H. S. Wilf. Wiley. 1960.

Digital Computers and Nuclear Reactor Calculations. W. S. Sangren. Wiley. 1960. This is a self-contained work on programming and numerical methods that goes into detail on the important computational problems of reactor design.

Analogue and Digital Computers. Edited by A. C. Haley and W. E. Scott. Newnes. 1960.

Analogue Computation. A. S. Jackson. McGraw-Hill. 1960. A very detailed and extensive survey of analogue machines, methods and applications, with a distinctly mathematical flavour.

NEWS

Change in technical education A major reorganization of the system of courses for technicians, craftsmen and operatives in technical colleges is proposed in the recent white paper 'Better opportunities in technical education' (Cmnd 1254, HMSO). Preliminary courses in evening institutes are to be discontinued and school leavers will immediately start at technical colleges. Courses are to be broadened and made more varied, so that they relate more closely to the needs of industry.

• At the Borough Polytechnic, Mr J. F. Douglas has succeeded Mr G. L. H. Bird as the Head of the Department of Mechanical Engineering.

UK COURSES

Imperial College, London—Department of Chemical Engineering. Reactor fuel element technology. Ten lectures on Thursdays from May 4–18. Introduced by Mr L. Rotherham, CEGB, and concluded by Mr L. Grainger, Assistant Director, AERE, Harwell. Fee: £5 5s.

Royal Institution of Great Britain, London Friday evening discourses, 9 p.m.—March 10, Energy, by Ronald King.

Harwell Reactor School Radiation protection course, no. 4, April 18–July 18. Senior Technical Executives course, no. 12, May 8–19.

Northampton College, London Developments in modern boiler plant. March 7 and 14, 6.30 p.m. Short course on Nuclear power plant design. May 1-12.

WHICH WAY WOULD YOU TAKE THE PYLONS?

Down in the valley, the town needs more power. The time's come to bring in a power line from the Grid. That means pylons, right across these fields, and on down into the valley.

There are perhaps a hundred paths the pylons could follow. *One* must be chosen. Not plotted arbitrarily across a map, but thoughtfully, carefully sited, so that pylons and cable strike the best possible balance with the landscape.

The Central Electricity Generating Board are just as concerned about this as they are about bringing in the power. For the nation has charged the Board with a double duty. Not only to maintain an efficient, economical electricity supply, but also to preserve the amenities of the country as they go.

That's why the new line will be planned so that it follows the dark background of a wood here; skirts a village there; crosses skylines in the most inconspicuous way to be found; and eventually reaches the town through its industrial suburbs.

These advertisements are appearing in the farming and country magazines. The Central Electricity Generating Board thank electrical contractors for their co-operation in the past, and know that they will do all they can to preserve the amenities of the countryside.

THE CENTRAL ELECTRICITY GENERATING BOARD C·E·G·B

People

by John Radford

THE NEW chairman of the US Atomic Energy Commission is to be Nobel Prize winner, **Glenn Theodore Seaborg,** 48, chancellor of the University of California at Berkeley. A leading nuclear scientist, Dr Seaborg was a co-discoverer of plutonium and it was for his pioneering work in the discoveries of several elements heavier than uranium that he shared the 1951 Nobel Prize in chemistry with **Dr Edwin McMillan,** also of the University of California. From 1946–1950, Dr Seaborg served on the AEC's General Advisory Committee and since 1947, he has been on the Committee of Standards and Units of Radioactivity of the (US) National Research Council.

Dr Seaborg takes the place of **Mr John A. McCone** who took office in July 1958. Though his term as chairman was not due to expire until June 1963, Mr McCone early this year tendered his resignation, effective on January 20, the date when the Kennedy administration took over in the USA. During his period of office, Mr McCone, a forceful administrator, was responsible for good working relations between the AEC and the Joint Congressional Committee on Atomic Energy and also for the 10 year civilian power reactor development programme aimed at developing competitive nuclear power by 1968.

The chief executives of the United Power Company, the company in which GEC–Simon Carves and Atomic Power Constructions have equal representation (see *Worldview*, February, p 53) are: **Mr A. L. G. Lindley,** chairman; **Lord Coleraine,** deputy chairman; **Col. G. W. Raby,** managing director; **Messrs H. Clarke, J. Mayer, R. N. Millar, O. J. Philipson, C. C. Vinson,** directors ; **Dr H. K. Cameron** and **Mr J. W. Ashley,** joint technical directors and **Mr W. Adams,** secretary.

Sir Alexander Fleck, former chairman of Imperial Chemical Industries Ltd, received the only full peerage conferred in the New Year Honours List. Other awards included: *Knights Bachelor:* **Mr Cecil Dannatt,** vice-chairman, Associated Electrical Industries Ltd; *Knights Grand Cross:* **Sir Ellis Hunter,** chairman and managing director, Dorman Long & Co; *CBE:* **Edward F. Newley,** Dep. Director, AWRE, Aldermaston; **Arthur A. Rubbra,** technical director, Rolls-Royce Ltd; **James B. Scott,** sales director, Crompton Parkinson Ltd; **Arthur J. Young,** managing director, English Electric Valve Company Ltd; *OBE:* **Wilfred R. Harvey,** manager, marine department, Babcock & Wilcox Ltd; **George D. Ireland,** chief engineer, Windscale and Calder works, AEA; **Wilfred G. Adams,** Senior Executive Officer, Ministry of Power; **Walter James Neal,** chief fire officer, AERE, Harwell; **Edward H. Ramage,** director, Sir Robert McAlpine & Sons (S. Wales); **William L. Roe,** Chief Metallurgist, Aiton & Co., Derby, and **Cyril Sanders,** Senior Experimental Officer, AERE, Harwell.

New appointments to the Board of the General Electric Company were announced recently and are to be followed by other appointments to strengthen the management. **Mr T. B. C. Kerr** is now deputy managing director; he was made director for Finance and Administration in 1959. The GEC also announced that **Mr E. H. Davison** has been appointed as Financial Director. He became Treasurer of Courtaulds Ltd in 1957 and that company's board has agreed to release him from his position so that he can take up his duties with the GEC on March 1, 1961. Both Mr Kerr and Mr Davison are members of a GEC Management Committee headed by **Mr Arnold Lindley,** chairman of the company. Other members are **Mr O. W. Humphreys** and **Mr R. N. Millar.**

Points from Papers

reports, meetings, conferences

RADIATION ACCIDENTS

Information about accidents in the atomic industry, not previously published, is now being received by a US non-government organization and is further disseminated in lists subject to continuing revision. (See also: *Nuclear Power*, October, 1960, pp. 77–80.) The two lists below, currently available, are taken to the end of 1960. The Partial List includes fires and explosions, as well as direct exposure to radiation or releases of radioactive gases to the atmosphere. The second list brings the total number of accidents connected with reactor operation up to forty.

The report on the Vinca investigation that re-enacted the events of 1958 is particularly useful in that it is a co-operative effort based on the work of experts from the CEA, Saclay; scientific staff from the Boris Kidric Institute, Yugoslavia; and scientists from Oak Ridge and the UKAEA. It shows how exposure studies can be made with the use of phantom bodies, and it outlines the latest methods used in dosimetry, for the calculation of neutron and gamma leakage, and for the evaluation of individual doses.

Partial list of accidents involving radiation. L. Goodman. Jan. 1961. 10 pp.

A few atomic reactor accidents. L. Goodman. Dec. 1960. Both available from Mr Goodman, Atomic Energy Technical Committee, IUD-AFL-CIO, Washington 6, DC.

Dosimetric investigation of the radiation accident, Vinca, Yugoslavia. G. S. Hurst *et al.* **Report TO/HS/22.** 69 pp. International Atomic Energy Agency. Available from *Nuclear Power.*

IMPROVED PWR PERFORMANCE

In the SSCR, spectral shift control reactor, reactivity control would be accomplished by varying the concentration of a D_2O-H_2O mixture. Changing the reactivity in this way offsets the long-term effects of burnout and isotope build up. Based on current technology and designed for immediate construction, analysis of a central station concept demonstrates reduced capital investment, reduced fuel costs, and conservation of fuel reserves through higher conversion.

Economics of spectral shift control. R. W. Deuster and Z. Levene, Babcock and Wilcox, (US). Bulletin AER-69. 5 pp. ASME Winter annual meeting 1960. Available from ASME or *Nuclear Power.*

FUEL ELEMENTS FOR HALLAM

Following a detailed development, fabrication and testing programme, the fuel element for the first core loading in the sodium nuclear power facility at Hallam is to consist of a cluster of stainless steel clad sodium bonded U 10 wt % Mo fuel rods. Casting was shown to be a feasible fabrication method and liquid pouring proved the only practical method of handling sodium to bond the fuel rods. Assembly problems were resolved by use of full-scale fuel element mock-ups, and final destructive tests of components indicated complete feasability.

Uranium alloy fuel element fabrication development for HNPF Core I. S. M. Cobb. Atomics International. **Report NAA-SR-5291.** 49 pp. Available from OTS $1.25 or depository library.

New Reports

Irradiation experiments with aqueous suspensions of plutonium dioxide. B. R. Harder and R. G. Sowden, AERE Harwell. **Report AERE R3537.** 20 pp. Available from HMSO *3s 6d*

A report on the Zenith exponential experiments. I. R. Cameron, G. H. Kinchin and J. E. Sanders. AEE Winfrith. **Report AEEW R36.** 43 pp. Available from HMSO *7s*

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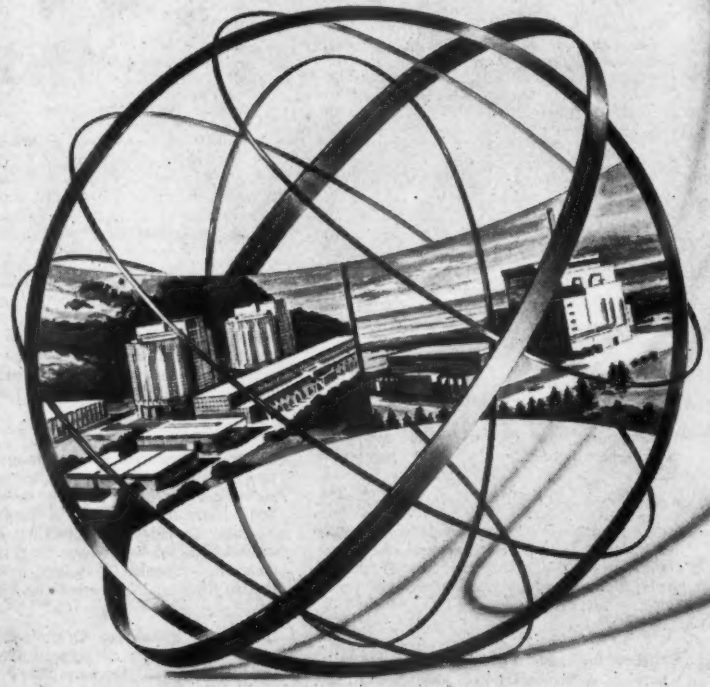

HEADQUARTERS: THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND ERITH KENT

396

Diary

1–2 MARCH
Symposium on **User experience of large scale industrial vacuum plant,** London. Details, Institution of Mechanical Engineers, 1 Birdcage Walk, London, SW1

2 MARCH
Oxidation in aqueous solution F. S. Dainton. Meeting, Chemical Society and Bristol Student Chemical Society, Department of Chemistry, The University, Bristol, 5.15 pm

Titrations in non-aqueous solvents, E. Minshall. Meeting, Chemical Society, Royal Institute of Chemistry and Society of Chemical Industry, Technical College, Brunswick Road, Gloucester, 6.30 pm

7 MARCH
Papers on **Fluidisation** from AWRE, Harwell. Institution of Chemical Engineers meeting, Burlington House, London, W1, 4 pm

Maintenance of heat exchangers, H. B. Merriman. Meeting, Institution of Plant Engineers, at Royal Society of Arts, John Adam Street, London, WC2, 7 pm

9 MARCH
Design application and selection of automatic control valves, Liverpool branch meeting, Society of Instrument Technology, 7 pm

Creep deformation, Liverpool Metallurgical Society meeting. Department of Metallurgy, Liverpool University, 7 pm

Chemical processing of power reactor fuels, F. F. Kemp. Meeting, Chemical Society and University College of Wales Chemical Society, Edward Davies Chemical Laboratories, University College, Aberystwyth, 5 pm

10 MARCH
Vapour phase chromatography, A. Verdin, Swansea. Meeting, Society for Analytical Chemistry and South Wales Section, Royal Institute of Chemistry

Annual general meeting, Institution of Chemical Engineers, North Western Branch, Midland Hotel, Manchester, 3.30 pm

Control problems of nuclear power stations, R. B. Quarmby, Gosta Green College of Technology, 7 pm. Meeting, Society of Instrument Technology

Some aspects of the radiation chemistry of aqueous systems, J. Weiss. Meeting, Chemical Society and Cambridge University Chemical Society at University Chemical Laboratory, Lensfield Road, Cambridge, 8.30 pm

13 MARCH
High energy radiation of rubber and rubber-like polymers, R. W. Pearson, Exchange Hotel, Liverpool, 7 pm. Institution of Rubber Industry, Merseyside section meeting

15 MARCH
Symposium on **burst slug detection in nuclear power stations,** Manson House, 26 Portland Place, London, W1, 7 pm. Details, Secretary of Instrument Technology

Graphite, L. C. F. Blackman, Stevenage, Herts. Details, DSIR, Warren Springs Laboratory, Cunnels Wood Road, Stevenage

17 MARCH
The use of nuclear magnetic resonance in the determination of chemical structures, joint meeting, Society of Chemical Industry and Fine Chemicals Group, 14 Belgrave Square, London, SW1

19–25 MARCH
Heat transfer; application of fundamental studies to practical problems, University of Sheffield. Details, Director, Extramural Studies, St John's, Crookes Valley Road, Sheffield

20 MARCH
Construction of nuclear power stations, D. M. Longman, Demonstration Theatre, Electricity House, Bristol, 6 pm. Meeting, Western Supply Group, Institution of Electrical Engineers

20–24 MARCH
Conference, **X-ray analytical methods,** the University, Manchester. Details, Conference, Secretary, Research & Control Instruments Ltd, Instrument House, 207 King's Cross Road, London, WC1

21 MARCH
Some factors in the safe operation of air separation plants, discussion meeting, Institution of Chemical Engineers, at the Geological Society, Burlington House, London, W1, 5.30 pm

21–26 MARCH
Electrical Engineers Exhibition, Earls Court. Details, Electrical Engineers ASEE Exhibition Ltd, Museum House, Museum Street, London, WC1

25–26 MARCH
Residential symposium, **instrumentation and control of nuclear reactors,** the Chesters, Bearsden, Glasgow. Meeting of Scottish Electronics and Measurement Group, Institution of Electrical Engineers

29 MARCH
Electronic instrumentation for nuclear power stations symposium, London School of Hygiene and Tropical Medicine, 3 pm. Meeting of British Institution of Radio Engineers

Future months

5–7 APRIL
Electrical contacts symposium, London. Details, Secretary, Institute of Physics, 47 Belgrave Square, London, SW1

10–15 APRIL
First International Congress on **Metallic Corrosion.** London. Details, Lt-Col. F. J. Griffin, Society of Chemical Industry, 14 Belgrave Square, London, SW1

OVERSEAS

21–23 MARCH
23rd annual American Power Conference, Chicago. Details, R. A. Budenholzer, Illinois Institute of Technology, 35 West 33rd Street, Technology Center, Chicago, Ill., USA

21–30 MARCH
139th meeting, American Chemical Society, St Louis. Details ACS, 1155 Sixteenth Street, NW, Washington, 6, DC, USA

27–31 MARCH
Third symposium on **Temperature**—its measurement and control in science and Instrument Society of America, American industry, Columbus, Ohio, USA. Sponsored by Institute of Physics, National Bureau of Standards

28–29 MARCH
Nucleonics in Flight, Dallas, Texas, American Nuclear Society Topical Meeting. Programme Chairman, N. M. Schaeffer, Convair, Forth Worth, Texas, USA

Industrial Literature

Hand tools. A new edition of the King Dick catalogue of hand tools is now available. It contains extensive details of nearly 2000 tools for use in many engineering applications.

★ **250**

Wrought zirconium. New from the ICI Metals Division is a booklet containing data on the mechanical and physical properties of ICI Zirconium 10 and 15 and the alloys —Zircaloy 2 and Zirconium 30, the latter manufactured under licence from AEI (Manchester) Ltd.

★ **251**

Stainless steel tubes. Detailed information on practically every aspect of s.s. is given in a publication from Sandvik Swedish Steels. Mechanical properties are included, followed by applications, working pressures, and grade and size selection.

★ **252**

Preferred circuits. The latest supplement, No. 3, to the US Navy handbook of Preferred circuits, contains seven germanium transistor circuits, two silicon transistor circuits and one vacuum-tube instrument servo circuit. (Price 55 cents.)

★ **253**

Flow measurement. Fischer and Porter's new catalogue covers their range of flow-metering transmitters — pneumatic, electric and electronic—in addition to secondary indicators, recorders, controllers and integrators.

★ **254**

Control valves. Publication 224A from Blakeborough presents design details and specifications for the complete range of Hammel-Dahl diaphragm flow regulation valves.

★ **255**

Zener diodes. The current issue of 'Rectifier News' (from International Rectifier) contains an article on the use of silicon zener diodes used as filament voltage regulators in a.c. applications.

★ **256**

Grinding indicator. For grinding operations where it is impossible to view the wheel itself, an electronic grinding indicator has been developed by Morris that shows on a cathode ray tube different kinds of 'Vee' signals. Catalogue ME.1 gives details.

★ **257**

Ultrasonic testing. The new Ultrasonoscopes catalogue, in addition to giving details of the range of equipment available, serves as a useful reference book by describing basic principles and some of the techniques used for the more common applications.

★ **258**

Speed measurement. The current issue of General Radio 'Experimenter' gives a detailed description of the new 'Strobotac', distributed in the UK by Lyons. Improvements claimed over other stroboscopes include high intensity white flashes, shorter flash duration and a 110 to 25,000 rev/min frequency range.

★ **259**

Electronic furniture. A wide range of Imhof racks, cases, consoles, handles and accessories are currently used in the electronics and electrical industries. A new catalogue has now appeared that describes every item available in ten languages: English, French, German, Spanish, Italian, Portuguese, Dutch, Swedish, Norwegian and Danish.

★ **260**

Laboratory glassware. Griffin and George have revised their catalogue of volumetric and lampblown glassware. It is a useful guide to equipment such as burettes, flasks, pipettes, butyrometers, soxhlet extractors and viscometers.

★ **261**

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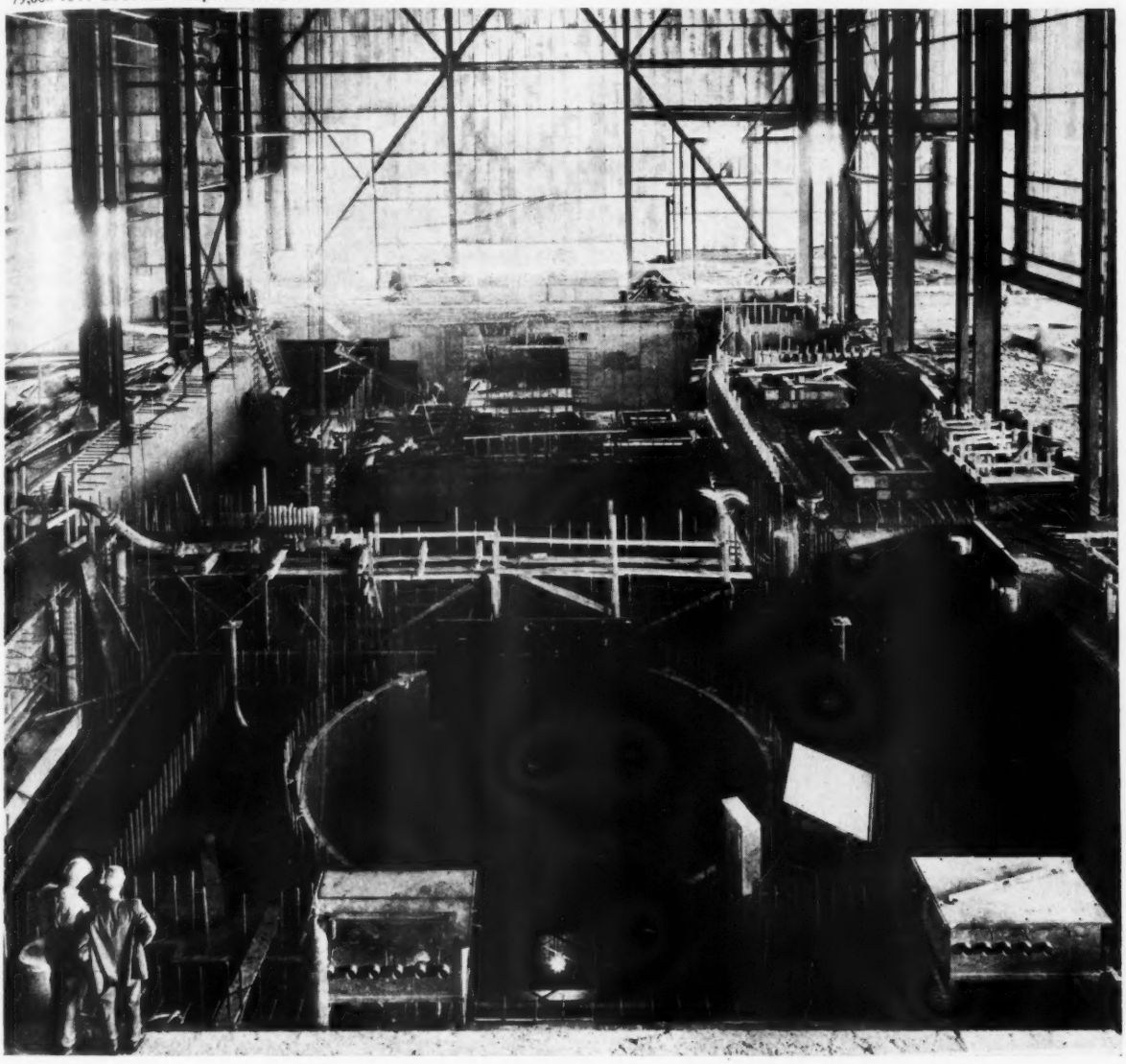

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Book Reviews

International law on atomic energy

This first volume in a series on legal documentation should prove a most useful handbook for those concerned with the growing international collaboration in the peaceful uses of nuclear energy: international and private lawyers, scientists, civil servants and industrialists. For the first time, the basic constitutional instruments of the principal international organizations exclusively devoted to the peaceful atom are in a single volume.

Pride of place in point of time goes to the Convention of 1953 establishing the European Organization for Nuclear Research at Geneva, CERN, and to the Statute of 1956 setting up the Joint Institute for Nuclear Research at Dubna.

It is of particular interest to have the Statute of the Dubna Institute published in English. Between CERN and this Institute there are many striking similarities: in aims, methods and, above all, in the statutory requirement that all results of scientific research work carried out shall be published and reported in such a way as to be freely available to the world. Both are, however, more concerned with fundamental research than with the practical application and uses of atomic energy. Both illustrate one particular form of collaboration, namely, an international joint undertaking with its own budget and research facilities, an internationally recruited staff and an international governing body.

The book sets out the two principal legal texts which form the basis for regional co-operation in Western Europe — that of establishing the European Atomic Energy Community (Euratom) and, on a wider organizational basis, that of the OEEC European Nuclear Energy Agency (ENEA). Both these organizations came into existence at the beginning of 1958, although the OEEC's Steering Committee for Nuclear Energy, which became the executive organ of ENEA, has been in existence since 1956.

The constitutional instruments of the three ENEA joint undertakings are also reproduced: the 1957 Convention setting up the European Company for the Chemical Processing of Irradiated Fuels (Eurochemic), the Halden Agreement of 1958 and the 1959 Agreement on the Dragon Project.

This first in the IAEA 'Legal Series' has concentrated upon the more developed international co-operative efforts; it has omitted reference to certain other multilateral nuclear activities, for example, those of the Organization of American States and the Asiatic Nuclear Research Centre at Manila in the Philippines. But it does include the famous Tripartite Declaration by the Heads of Government of the United States, Canada and the United Kingdom of 1945 as well as the Tripartite Agreement of the same Governments of 1956. These last two agreements are only of minor interest and could well have been omitted.

Multilateral agreements (Legal Series No. 1) International Atomic Energy Agency, Vienna 1959 258 pp Price 15s

J.L.W.

The West German Nuclear Scene

Taschenbuch für Atomfragen, 1959 Festland Verlag, Bonn 1959 288 pp 17s 6d

Atom ABC compiled by W. D. Muller Econ-Verlag, Düsseldorf 1959 322 pp Price DM12·80

Nuclear Energy Terms: a bilingual glossary; English-German, German-English compiled by A. Z. Redding Nuclear Translations Services, New York 1960 121 pp Price $3

Nuclear Physics and Atomic Energy terms by G. J. Béné *et al* Elsevier, Amsterdam and London 1960 213 pp Price 30s

Whilst Germany made a late start in the nuclear field, there seems little doubt that she has taken the challenge seriously, judging by the number of research organizations that have been set up and the type of nuclear facilities provided. The extent of this effort can be assessed by looking at the 'Atomic pocket book' which serves as a useful guide to the German atomic industry. Compiled by experts, it gives full details of all the relevant international, national and district organizations concerned with its development.

The 'ABC', also intended for the German reader, is more than a dictionary. Its scope extends beyond the definition of terms in nuclear physics and reactor technology to include organizations, names of reactors, abbreviations and current expressions—giving origin and meaning.

The increasing number of German articles, technical papers, specifications and industrial brochures makes the provision of specialist glossaries a matter of urgency. Another difficulty to be overcome by the technical translator is the use of a number of German equivalents to single English terms. Mr Redding's glossary, containing over 1200 terms, tries to solve this problem by giving multiple entries where they exist, treating the first entry as the preferred word if a distinction is possible.

Elsevier's glossary, one of a series intended for interpreters at international conferences, covers much of the same ground as above but with the addition of other terms relating to general physics and technology. It is a more ambitious publication, however, terms are given in French, German and Russian with the principal arrangement by the English word. There are also separate alphabetical indexes for these other languages that cross-reference to the main sequence.

New books

• *Auswirkungau atomarer Detonationen auf den Menschau* by O. Messerschmidt Karl Thiemig, Munich 1960 293 pp Price DM48 ★ 263

• *Materials for nuclear engineers* edited by A. B. McIntosh and T. J. Heal Temple Press, London 1960 373 pp 75s ★ 262

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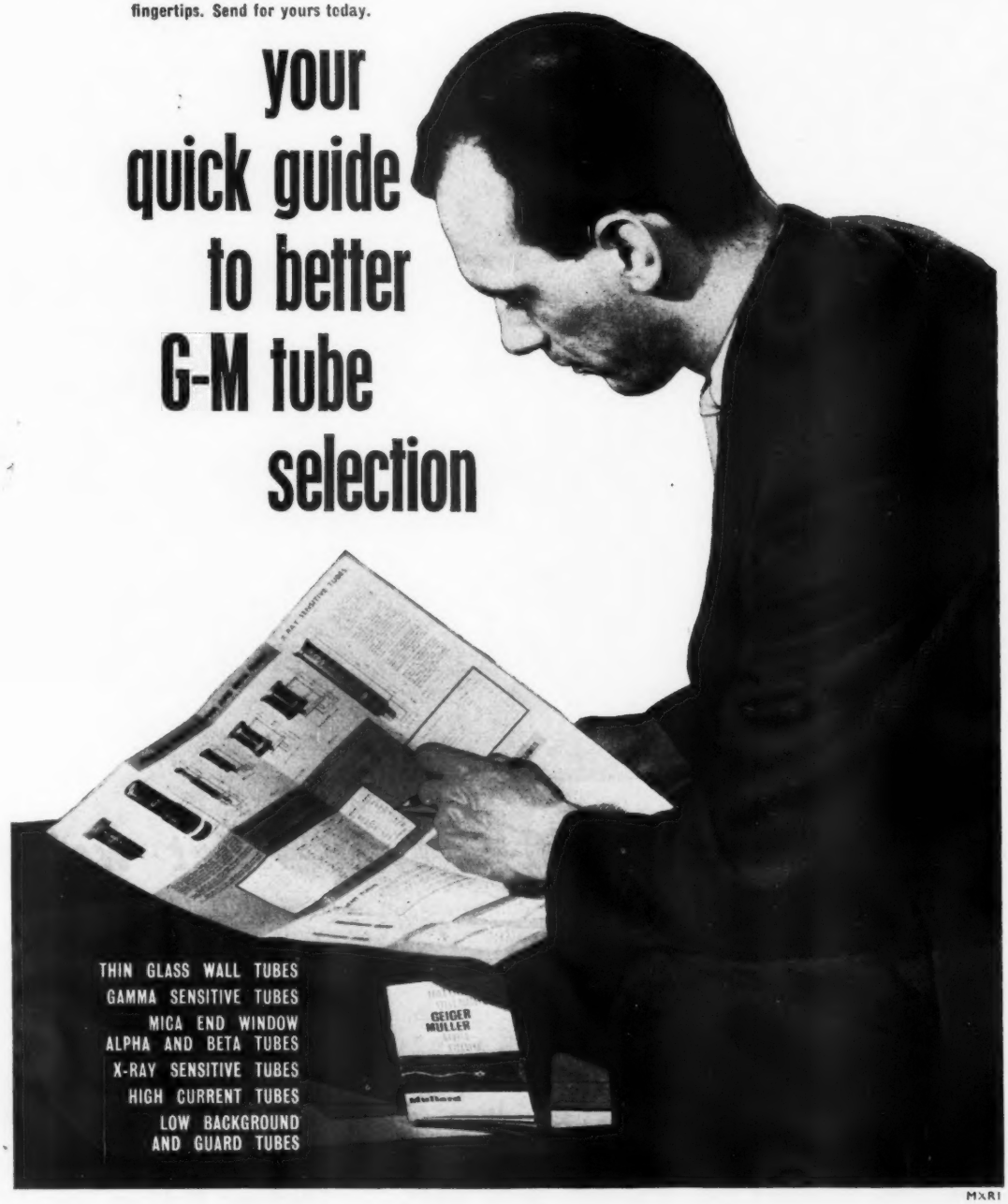

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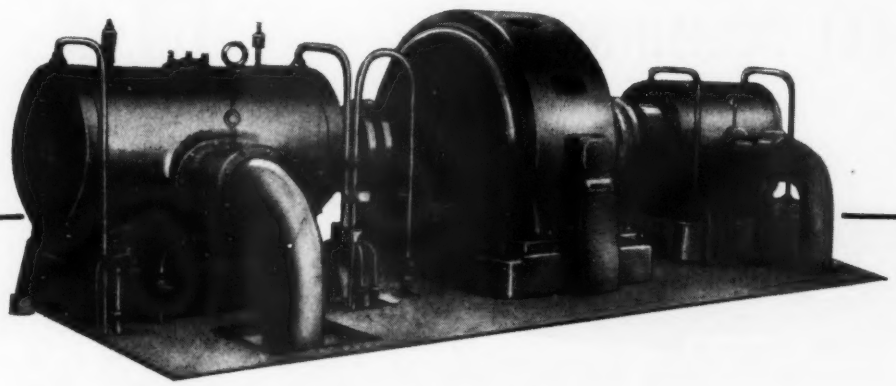

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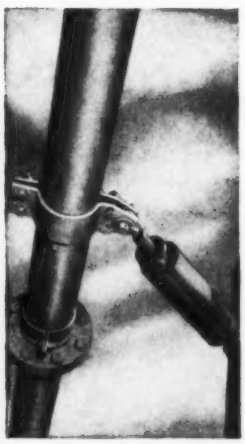

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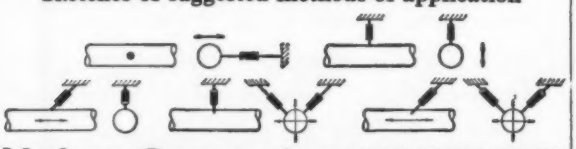

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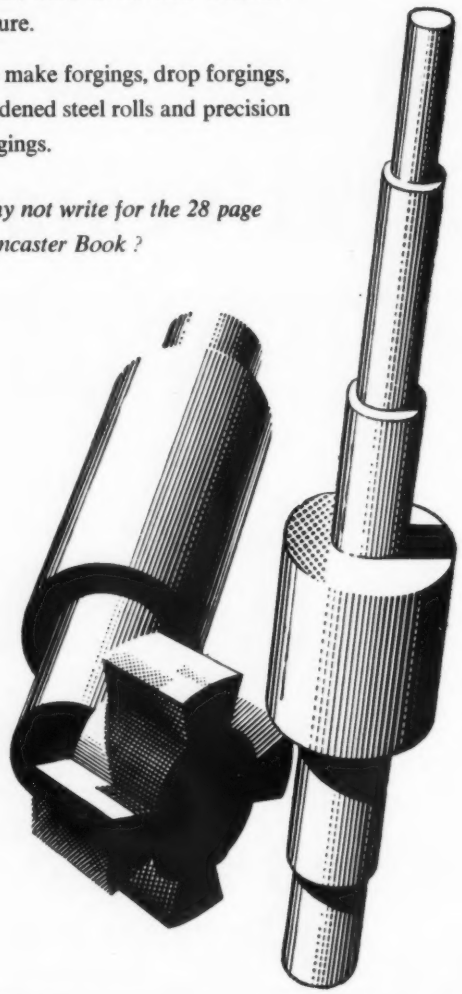

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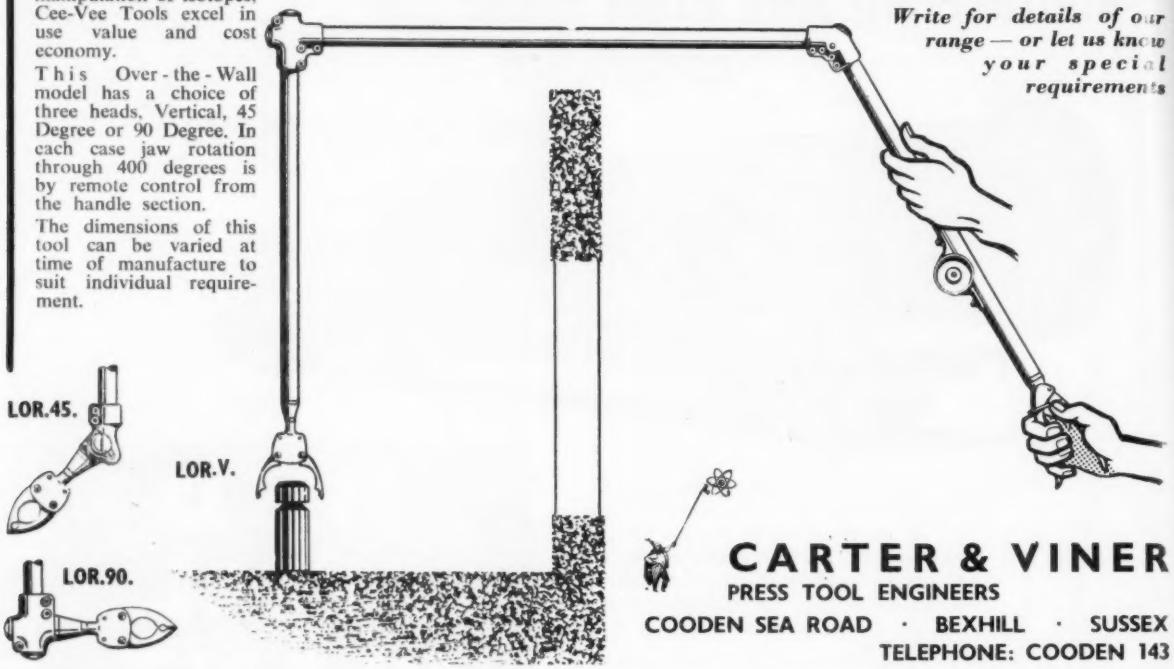

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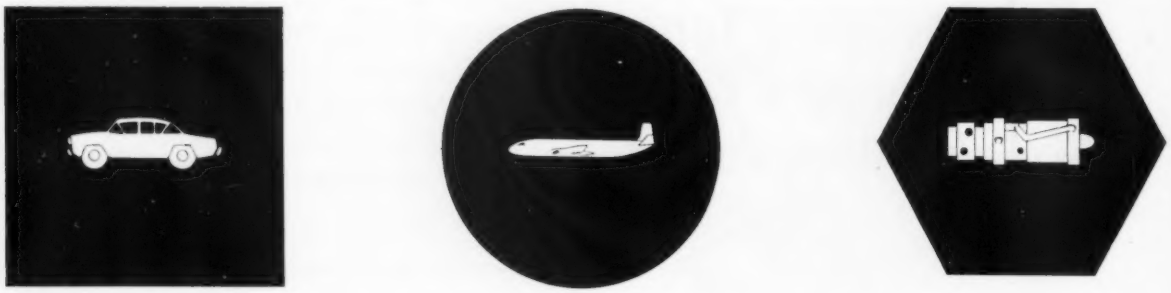

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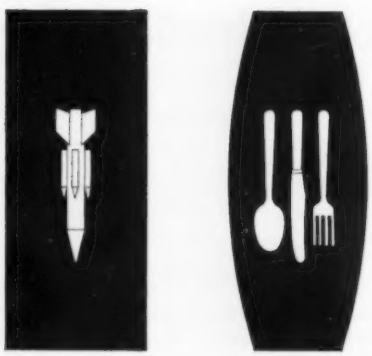

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E' talvolta difficile all'inserzionista di indicare in uno spazio ristretto tutti i particolari dei suoi prodotti. Qualora desideraste ricevere più ampie informazioni a questo riguardo, favorite segnare il numero appropriato sul cartellino qui accanto ed inviare quest'ultimo a NUCLEAR POWER.

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Se hace a menudo difícil para los anunciantes dar en un espacio limitado todos los detalles técnicos sobre sus productos. Si desea ulterior información, marque los números apropiados en la tarjeta opuesta y mándela a NUCLEAR POWER.

Информация для читателей

Часто бывает трудно рекламирующим лицам давать все технические подробности своей продукции в рекламе. Если Вам понадобятся добавочные сведения, то просто отметьте соответствующие номера на каточке на противоположной стороне и отправьте в NUCLEAR POWER.

讀者詢問服務

在廣告上以有限的地方來解釋一些專門技術，及它們的功果，的確是有受限制的困难。若讀者欲要知道一些詳細的情形就請將可貴的表格，取一號下來將閣下有疑問的項目，用筆勾一下即寄給子能工程雜誌即可。

読者サービス

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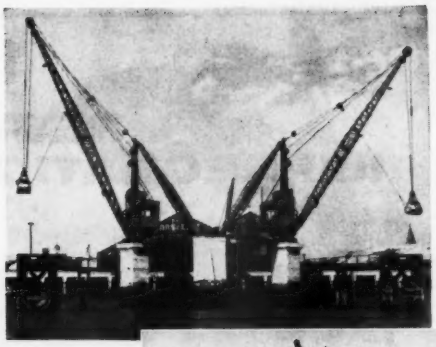

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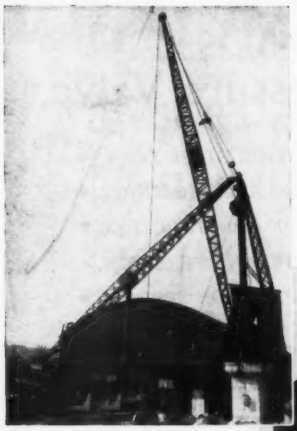

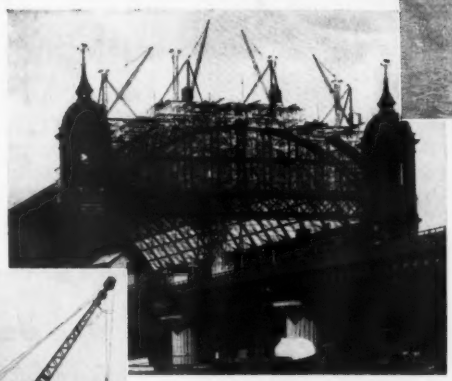

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of wire-wound components under vacuum

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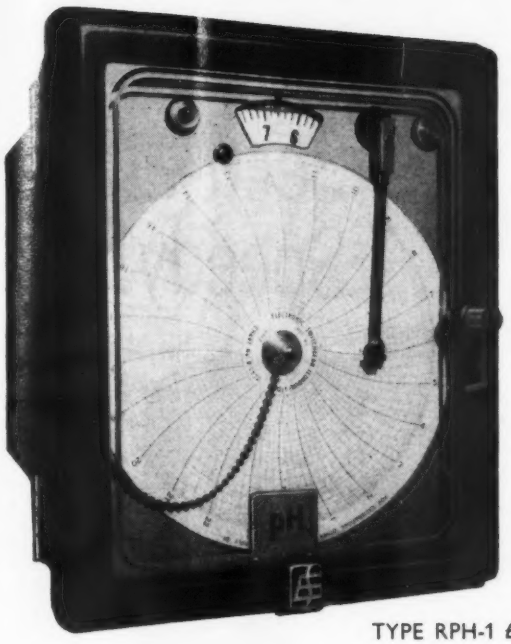

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are performed by a single instrument connected to a suitably selected pH electrode system.

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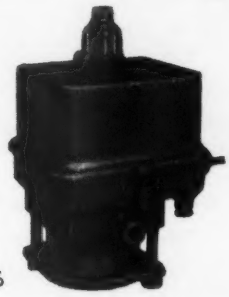

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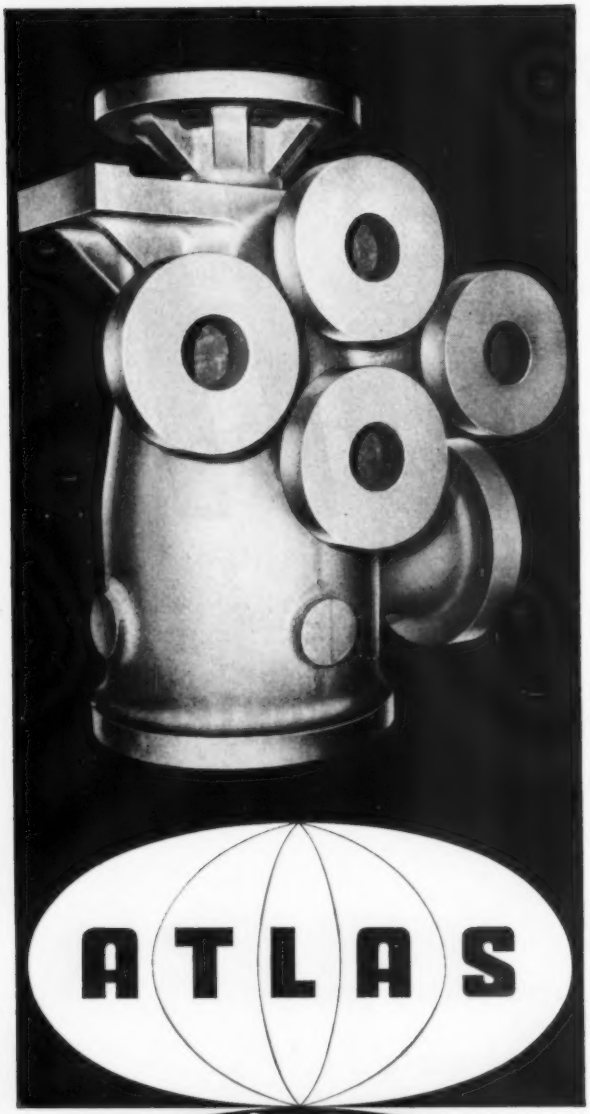

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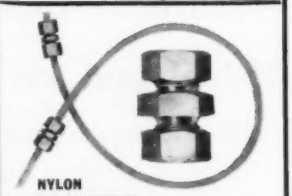
Simple! Secure! Speedy!

SIMPLIFIX COUPLINGS

STANDARD FITTINGS

For use with copper tube up to 2" o.d. Annealed and half-hard tube available from stock.



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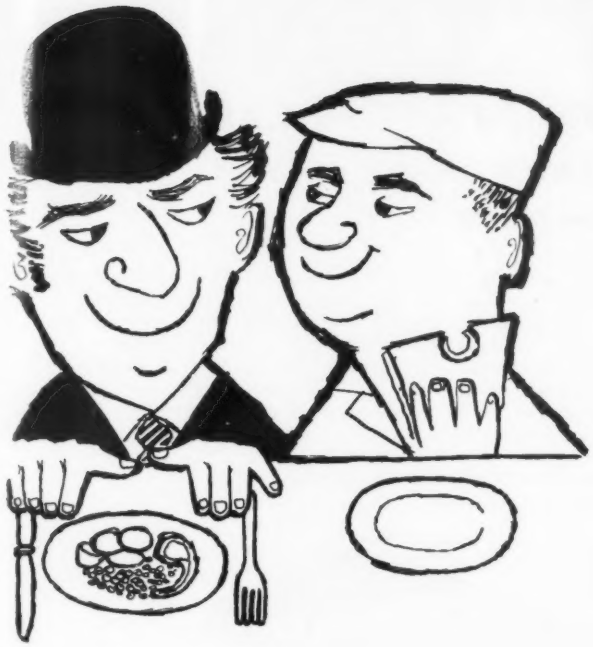

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We like to see a job well done. And we like to see our customers happy! Getting our teeth deeply embedded in to our customers' problems—no matter how specialised and individual—is the backbone of the MVC Service!

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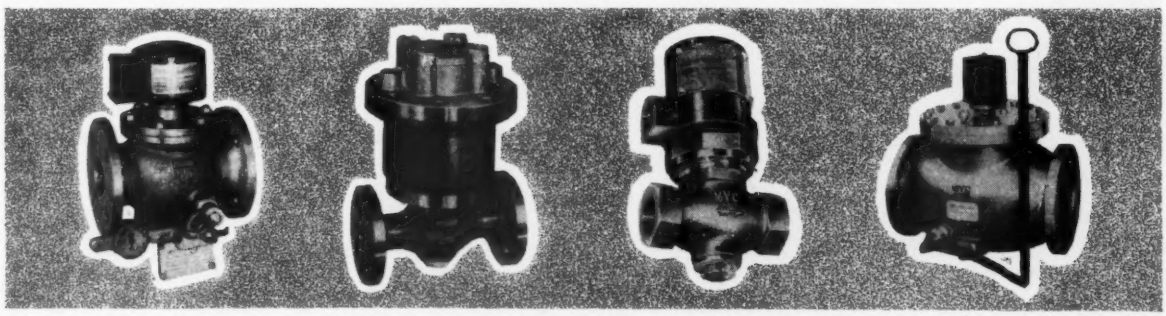

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POWER UNIT

type N.103

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OUTPUT VOLTAGE Continuously variable between 300 and 3,300 volts positive or negative, with an accuracy of ± 1% of dial reading.

OUTPUT CURRENT At the low-impedance output, up to 1mA.

OUTPUT IMPEDANCE Low-impedance output varies with voltage settings but does not exceed 3,000 ohms. High-impedance output 10 megohms.

STABILITY AND RE-SETTING ACCURACY Stability for mains variations of ± 10% is ± 0.05%. Drift due to all other causes is within the following limits for the periods stated: 1 hour ± 0.05%, 100 hours ± 0.1%, 1,000 hours ± 0.2%.
A stand-by switch is provided and when the unit is switched on after a stand-by period any given voltage will be within ± 0.05% of its previous figure.

RIPPLE AND PULSE CONTENT Ripple, noise and spurious pulses have a maximum level of 500 microvolts at 3,300 volts H.T. at the low-impedance output. At the high-impedance output this is reduced to below 100 microvolts.

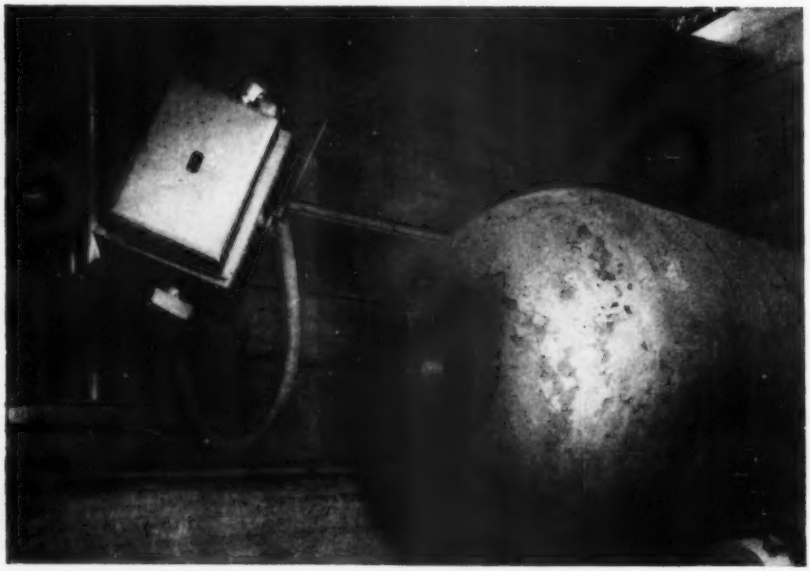
This power unit supplies the high voltage required by most types of counters used in nuclear physics, especially scintillation counters and other proportional counters which require extreme stability.
It is of the H.F. oscillator type with a specially designed feedback amplifier for stabilisation. Very careful design reduces ripple and spurious pulses to such a level that external filters are not normally required.
There are two outputs: high-impedance for use when absence of pulses and ripple are of paramount importance; and low-impedance for use when a greater current is required.
Power unit N.103 is normally supplied for rack mounting but is also available in a metal case.

DYNATRON

DYNATRON RADIO LIMITED
Nucleonic and Electronic Division, Maidenhead, Berks.
Maidenhead 5150 (10 lines)

SCALERS · PULSE ANALYSERS · POWER UNITS · PULSE AMPLIFIERS · INSTRUMENT RACKS

THICK PLATE RADIOGRAPHY AND MOBILITY



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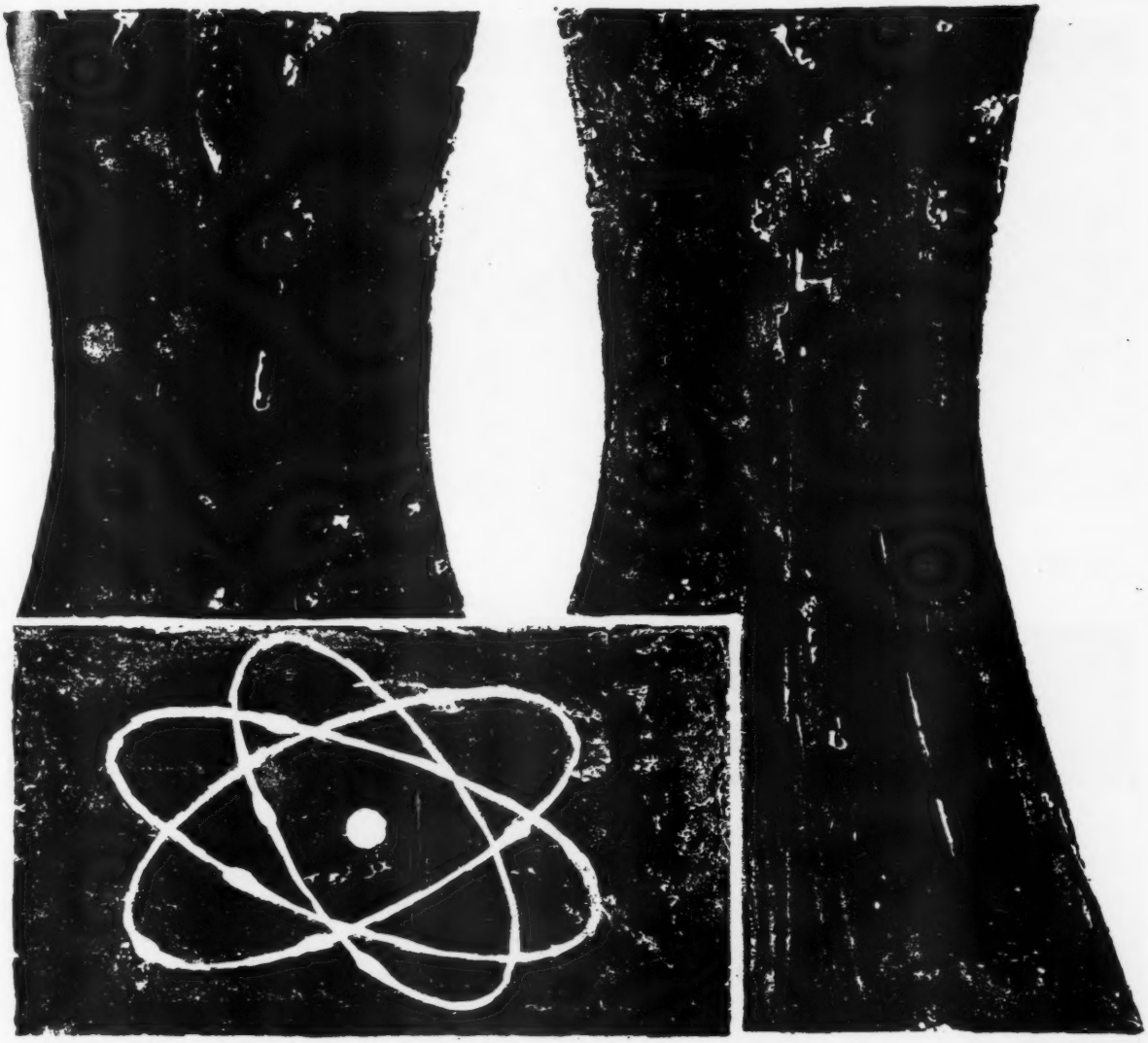

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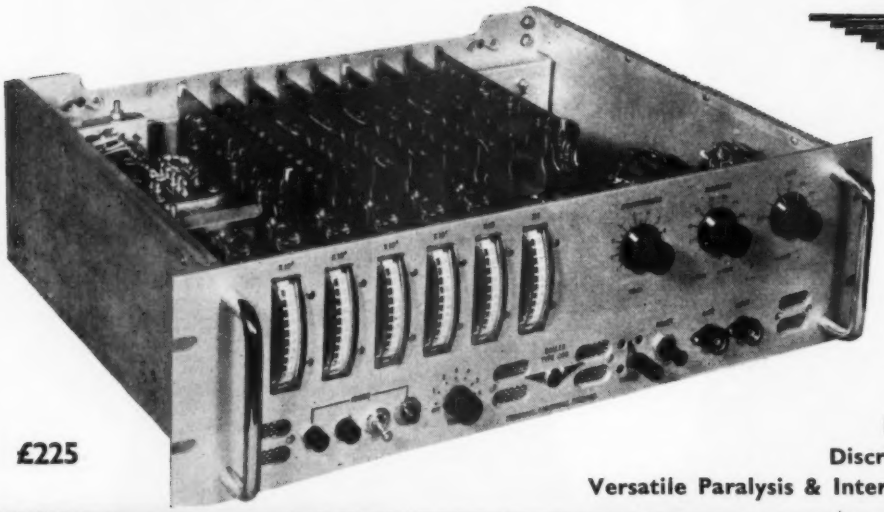

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Discriminator Ratio 20: 1
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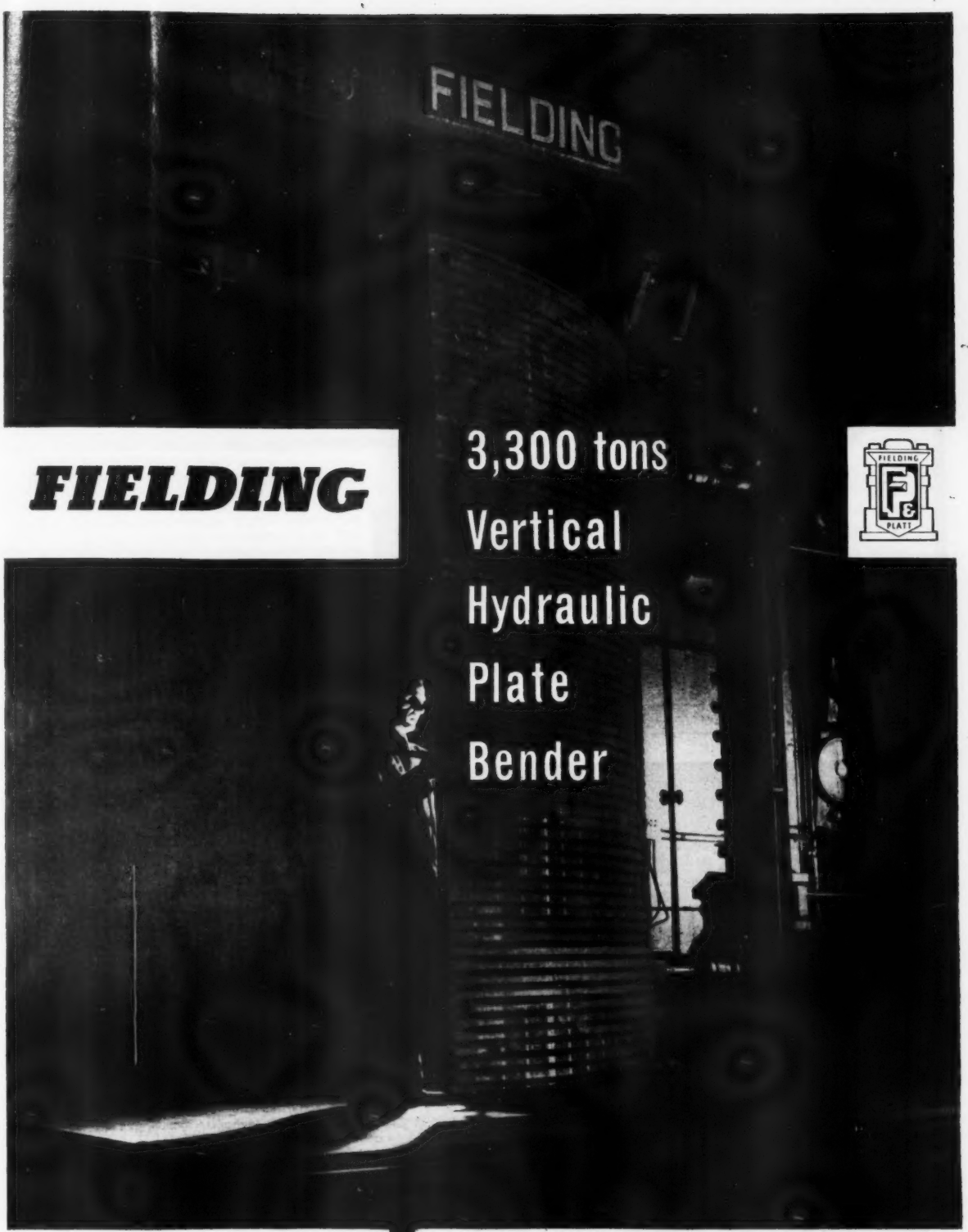

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Model GR-6 is loaded with Cs-137 to provide a flux of 5000 R/hr at an external dosage of less than 2 mr/hr at 1 foot from surface. Loading with fluxes to 12,000 R/hr available. Model GR-9, loaded with Co-60, provides flux level of 100,000 R/hr at a fraction of the external dosage level of less than 5 mr/hr at 1 foot from the surface. May be loaded for fluxes to 1,000,000 R/hr and remain within the stated external dosage level.

U.S. NUCLEAR CORP.

Fast Neutron Counter

The Model FN-1A Fast Neutron Counter—Scintillation Type—has three ranges, 0–50, 0–500 and 0–5000 neutrons/cm²/sec. It features an insensitivity to gamma radiation to 1 R/HR. Using a 2 in. diameter by $\frac{1}{4}$ in. thick ZnS plastic crystal, the instrument is splash proof, shock resistant and capable of operating up to plus 130 degrees F. High voltage power supply, amplifier-trigger and meter accessories are supplied on transistorized, plug-in cards.

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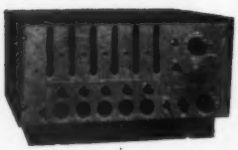

Computer Scaler

Model QS-6 READ-O-MATIC. An all-electronic computer scaler with a count storage and display channel and an electronic timer channel. It is a true events-per-unit-time computer for work involving medium and long time base intervals encountered in nuclear, electronic, industrial and other applications in measurement and control. Computed counting rate is displayed with decimal point properly placed.

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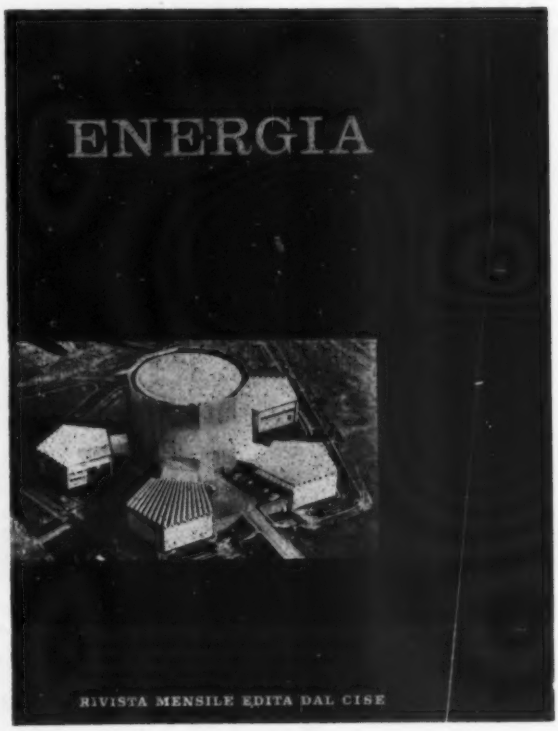

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a monthly journal published by **CISE**, Italian nuclear research centre.

It was the first and is still the only journal in Italy dealing with nuclear research and applications. Its high level content consists of:

★ original contributions (in English) on the results of studies and researches carried out by **CISE** or other nuclear laboratories;

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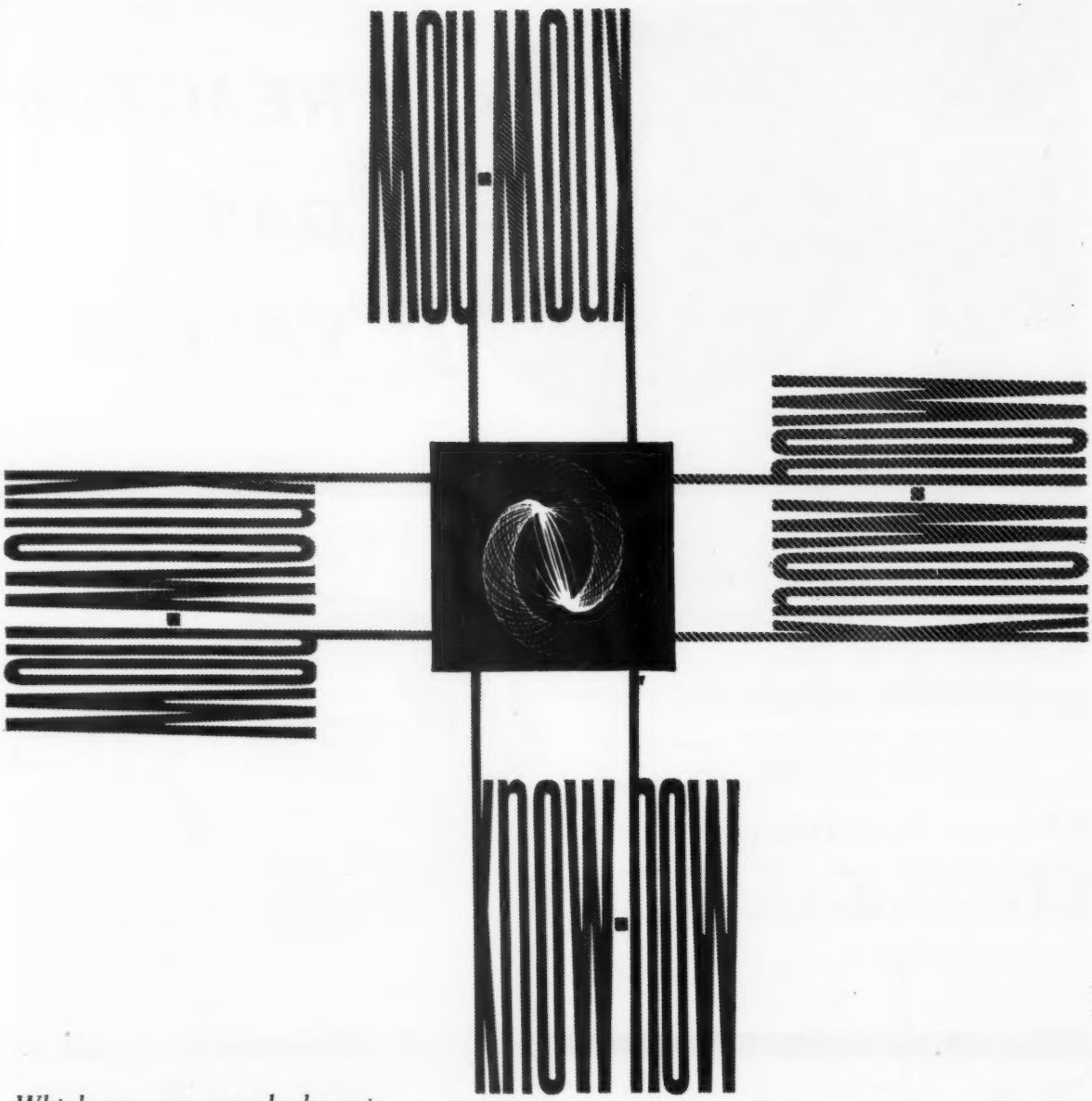

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If therefore you have a Development or Production problem, our Nuclear Energy Division will be very pleased to help you. Won't you pay a visit to the Gosport Factory and see what we can do ?

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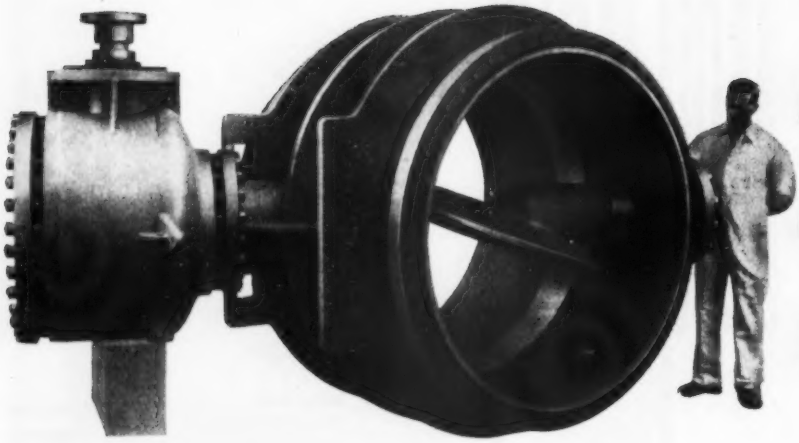
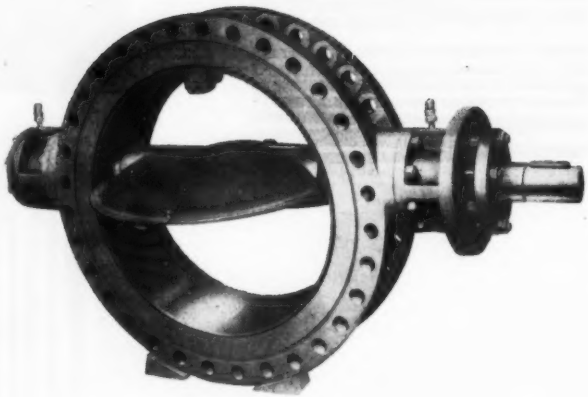


REACTOR GAS VALVES

Specially developed for high temperature gas duct service, Blakeborough "Cone-Seal" and "Stress-Seal" Butterfly valves have aroused particular interest in the nuclear field. The "Cone-Seal" construction is applicable to size up to 42 in. bore; the "Stress-Seal" from 36 in. upwards. Both give tight closure, or shut-off to very fine leakage tolerances, even under severe thermal shock conditions. A third type, for throttling duty only, is also available.



Valve Type	No. and Size	Reactor Installation	Duty (CO_2 Circuit)	Design Conditions
Stress-seal	32 60 in.	**Berkeley** Power Station	Main Duct Isolating	137 psi gauge, 716°F
	8 66 in.	**Tokai Mura** Power Station	" " "	230 psi gauge, 797°F
	16 78 in.	**Dungeness** Power Station	" " "	295 psi gauge, 788°F
Cone-seal	8 24 in.	**AGR, Windscale**	" " "	300 psi gauge, 1067°F
Throttle	12 66 in.	**Trawsfynydd** Power Station	Main Duct Throttle	264 psi gauge, 572°F
	12 42 in.	" " "	Bypass Duct Throttle	264 psi gauge, 572°F

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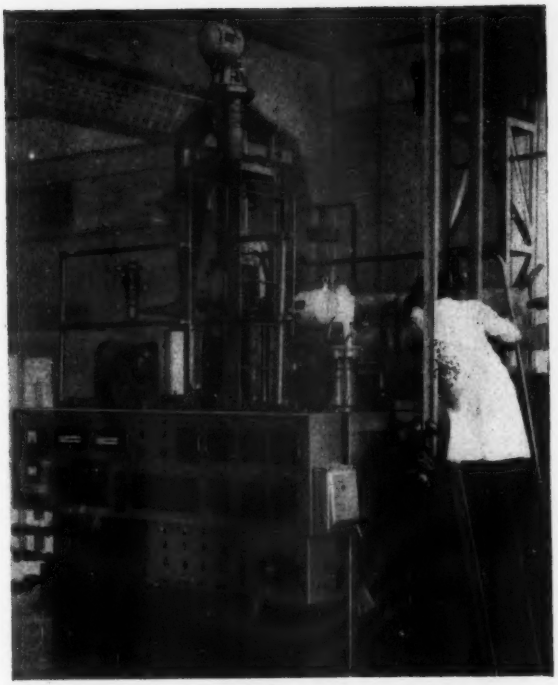
Do you employ vacuum Plant fitted with a "SPEEDIVAC" Pirani-gauge head?



it incorporates a ready-made, sensitive LEAK-DETECTOR

AND HERE'S HOW TO MAKE THE BEST USE OF IT

Any "Speedivac" series 5B or 6A Pirani type gauge head fitted to a vacuum plant can be plugged directly into this specially designed control unit to provide a hydrogen/Pirani leak detector with maximum sensitivity of 10^{-2} litre micron/sec. No other control units or galvanometers needed, just a "Speedivac" Pirani gauge head and the Model LT6A, which can be transferred from plant to plant as required without interfering with the existing instrumentation.

The Model LT6A control unit supplies the Pirani head with a.c. and any out-of-balance signal caused by the presence of detector gas at the head is amplified and fed to a phase sensitive detector. The signal is indicated by a centre zero milliammeter and four ranges of sensitivity are provided as well as zero balance controls.

If you have a vacuum plant fitted with "Speedivac" Pirani gauge heads, then you need an LT6A leak detector control unit.

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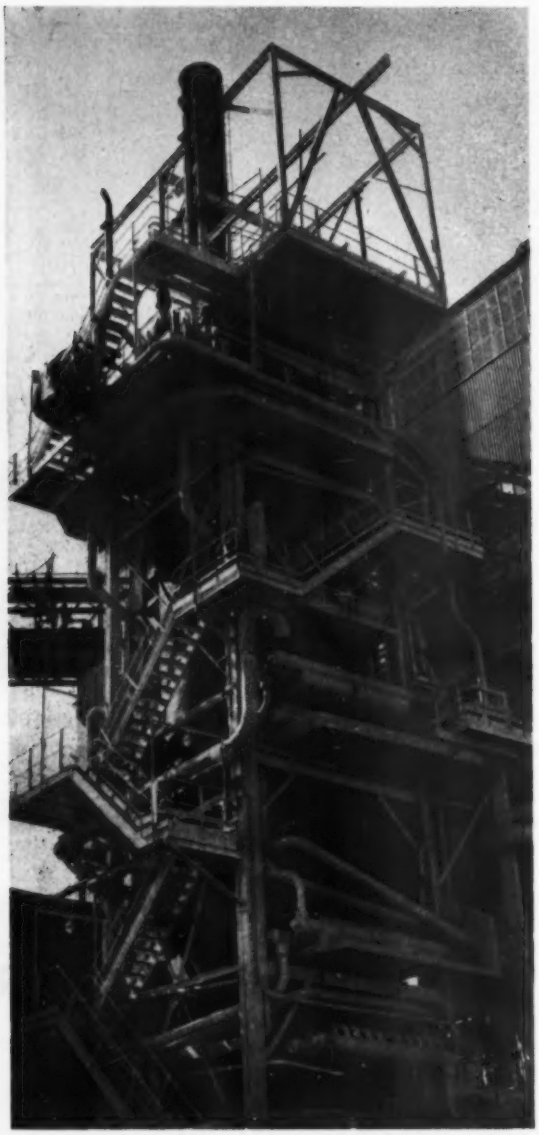

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at Calder Hall . . .

Vital installations, including sub-station switch rooms, at the Atomic Power Station are guarded against fire risk by a highly sensitive Kidde Detection system.
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Two counter tubes in a separate probe

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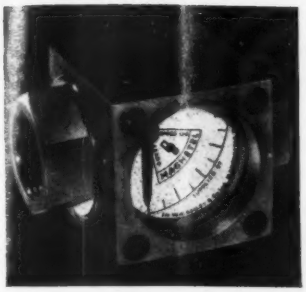

New flow indicator for opaque liquids

The **MAGNETEL**

The Magnetel is a flap type indicator—with a vital difference. A magnet set into the flap controls the indicator pointer, eliminating the need for springs and mechanical linkages. The Magnetel is a sensitive instrument suitable for liquids of almost any viscosity. A special model is available for use with liquids containing ferrous particles, and the flap can be arranged to permit flow in either direction. All parts are accessible for maintenance without disconnecting the pipe line. Available in sizes from ¾ in. to 2 in., the Magnetel supplements Bailey's already famous Telicator range of Rotary Flow Indicators.

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Stainless Steel Wire, to this specification, is already being supplied by us in ever increasing quantities to meet the specific requirements of Nuclear Engineers and Designers. We shall welcome your enquiries for this and all other types of Austenitic Stainless Steel Wire.

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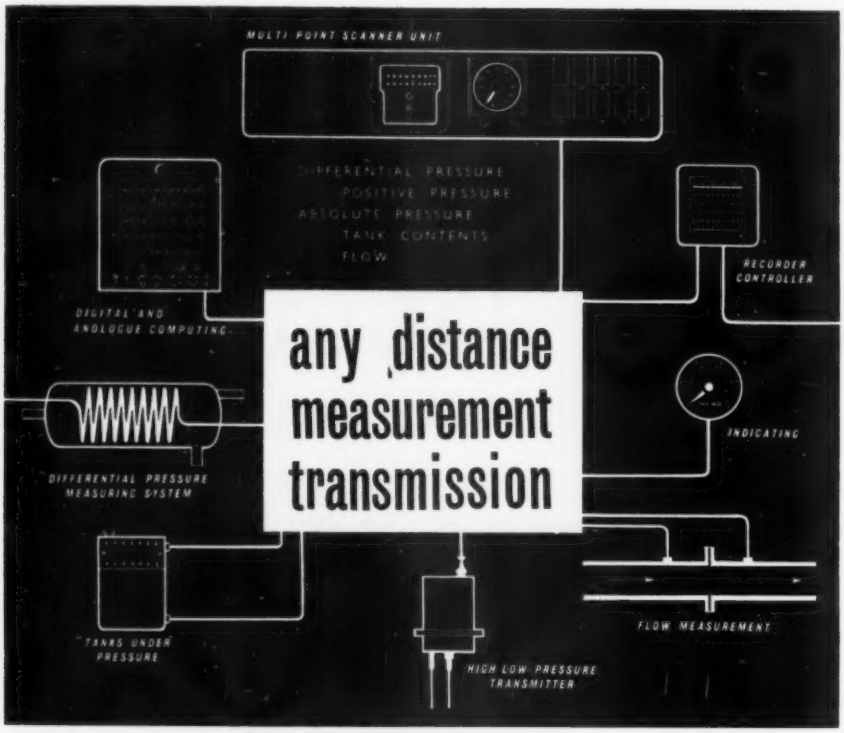

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Undoubtedly the answer to all air and hydrogen cooling problems is PREMIER. PREMIER closed circuit coolers are among the most highly efficient and economical in the world—installed in such important power stations as Meaford, Poole, Uskmouth, Hams Hall "C", Darlington, Bold "B", Stockport and Johannesburg; and hydrogen coolers and heat exchangers in hand for Hunterston Atomic Power Station and many other overseas works and power stations, large and small.

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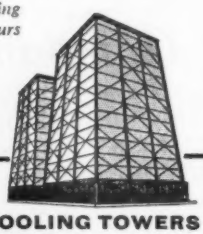
WE *do the designing ourselves.*
WE *manufacture our own plants.*
WE *erect the plants ourselves.*
WE *guarantee the performance.*



PREMIER COOLING TOWERS

THE PREMIER COOLER & ENGINEERING CO. LTD.
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TEST SIEVE SHAKER *for* accurate particle size analysis

Accurate and consistent results are the features required of a test sieve shaker for the sieve analysis of the particle size range of material. Simply vibrating or shaking test sieves by hand is not good enough for the standard of accuracy required these days. Vibration alone tends to aggregate rather than to segregate particles and shaking test sieves by hand is not only tedious but inevitably produces inaccurate results.

The **Inclyno Test Sieve Shaker** incorporates a double movement that jolts and spreads the test material ensuring perfect segregation of the various particle sizes and presenting the maximum number of apertures for undersize particles to fall through each sieve. Three models available for all sizes of standard test sieves and supplied complete with motor and inbuilt automatic time switch covering test periods up to 60 minutes.

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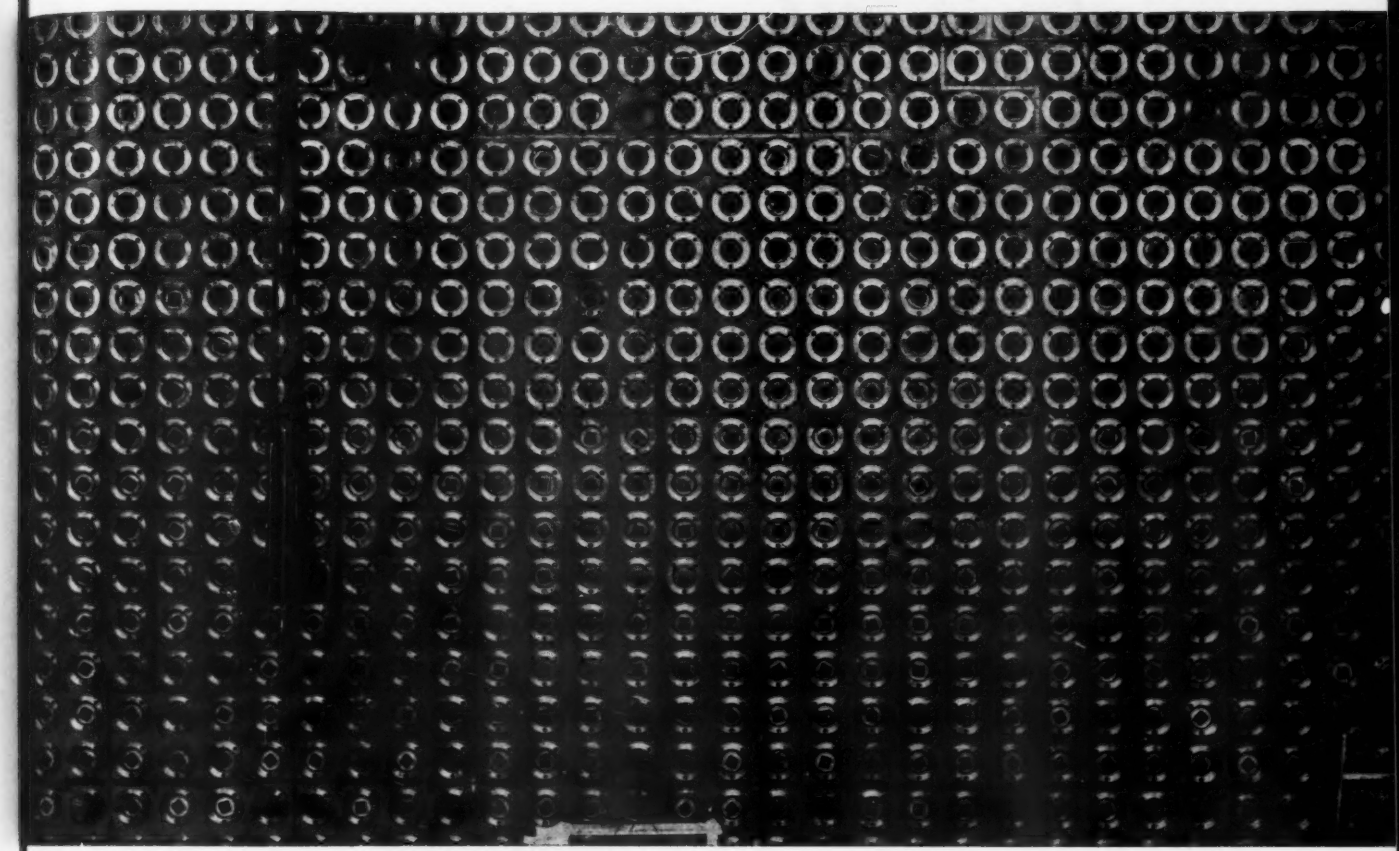

What is the most important piece of machinery in your factory ?

What would be the cost per day to your business if it were to break down ?

It is now possible to cover the loss of profits resulting from such a breakdown as well as the cost of repairing the machine itself.

Policies can be issued to meet the particular requirements of any business.

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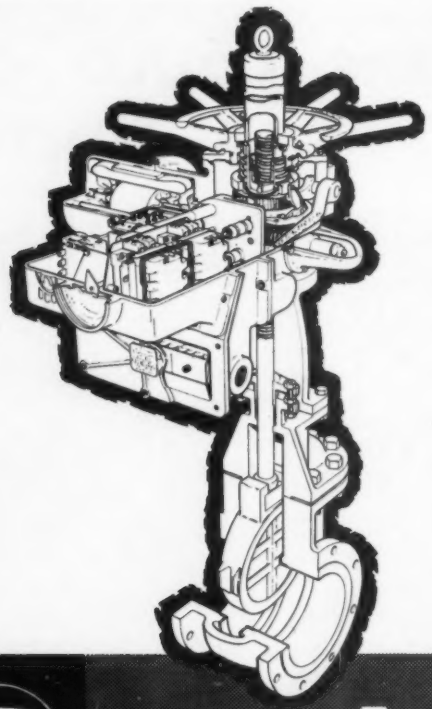

Rotork

international valve control

Rotork, for a long time the only Company in Britain specializing in valve motorisation, is now the only British Company with an *international* approach to valve control requirements.

THE ACTUATORS.
The Rotork 'A' range of actuators in standard form meets most requirements but can also be supplied to comply with any industrial or national specification. The range covers the power requirements of every type or size of valve.

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The electrical equipment and circuitry provide a flexible, versatile system which meets every type of control requirement, including local or remote pushbutton, automatic operation from data, sequence control and interlocking with other actuators or associated equipment etc.

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Name any big company in a valve-using industry and it is almost certain that you have named a Rotork customer.

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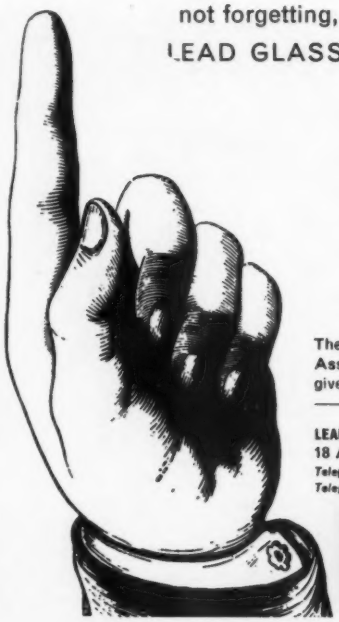

The technical officers of the Association are always glad to give individual assistance.

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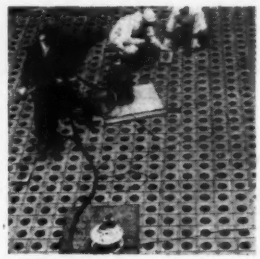
CLEAN CONDITIONS ARE ESSENTIAL



Simplex model removing dust within No. 1 reactor at Bradwell, on 25th June, 1960.
Photo by kind permission of The Nuclear Power Group, Bradwell and the Central Electricity Generating Board.

New Welbeck Master Cleaners contribute to Britain's great Nuclear Power Programme.

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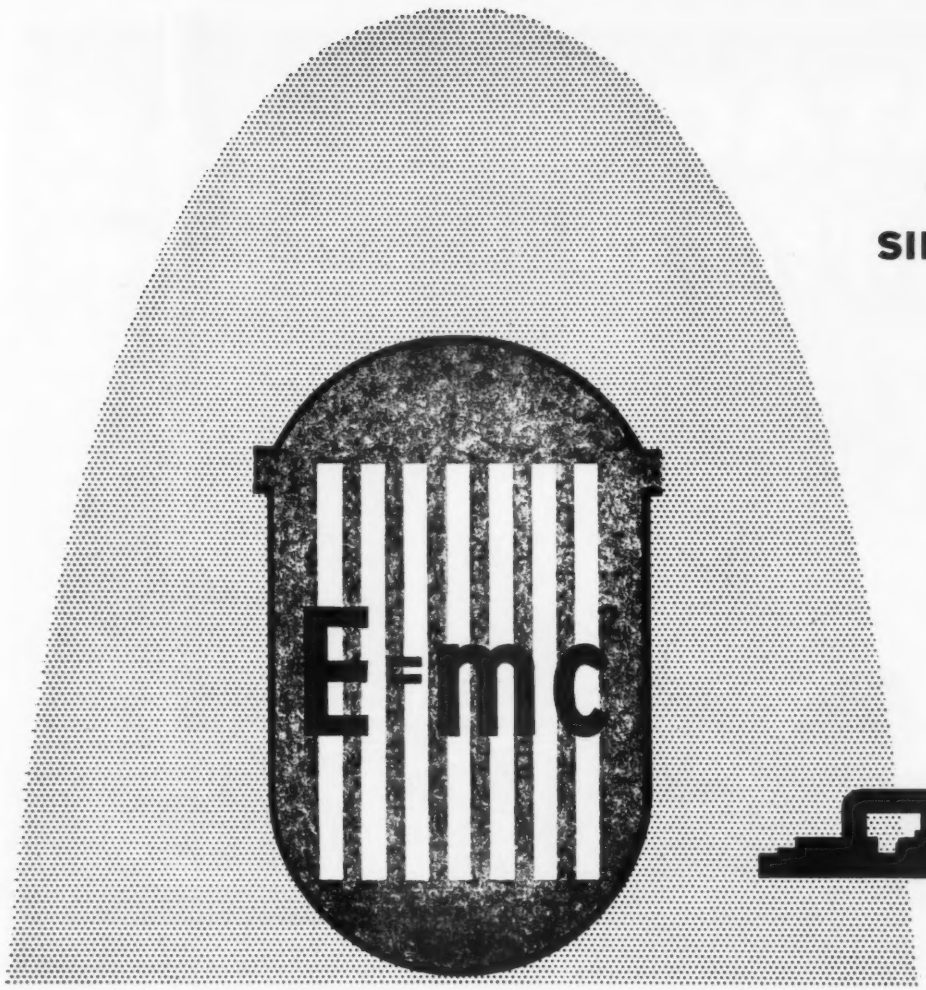

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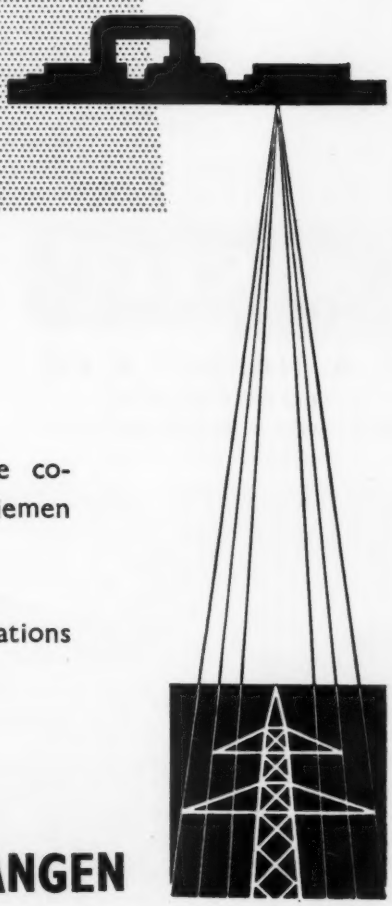

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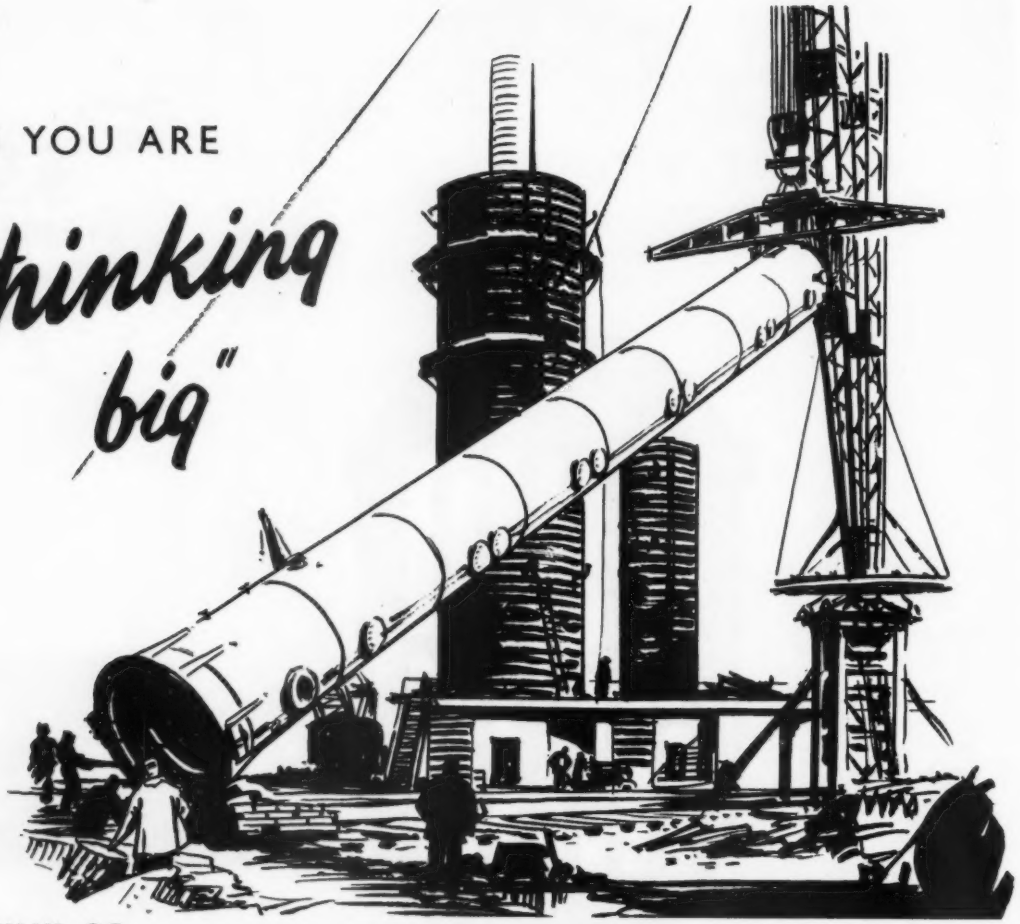

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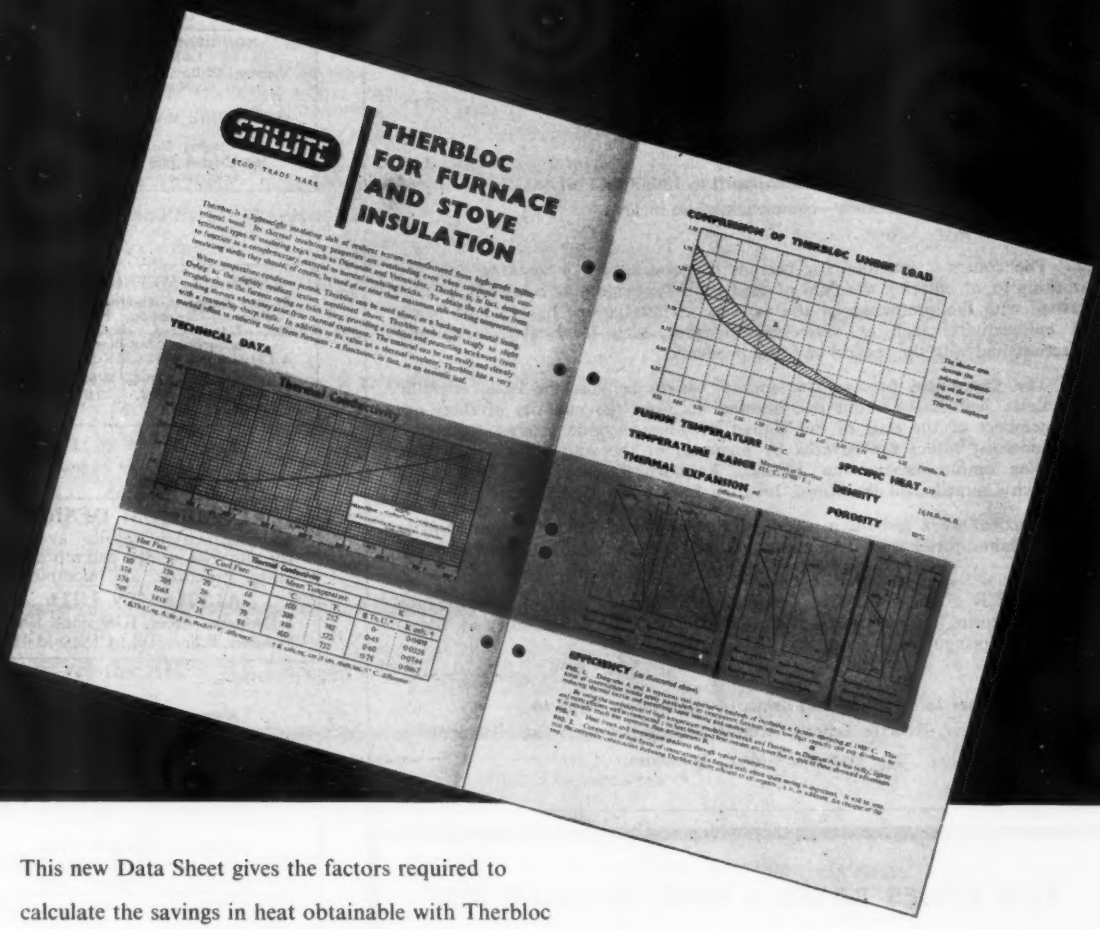

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The course is intended for persons of good academic standing who are working in or entering the field of Radiation Protection. It is especially concerned with the protection of the workers in installations having high levels of radioactivity, such as radiochemical plant, high level laboratories and reactors, and with the control of waste products.

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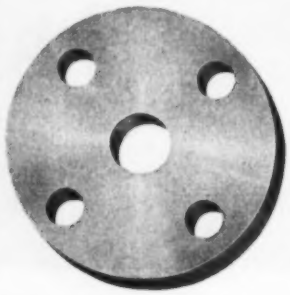

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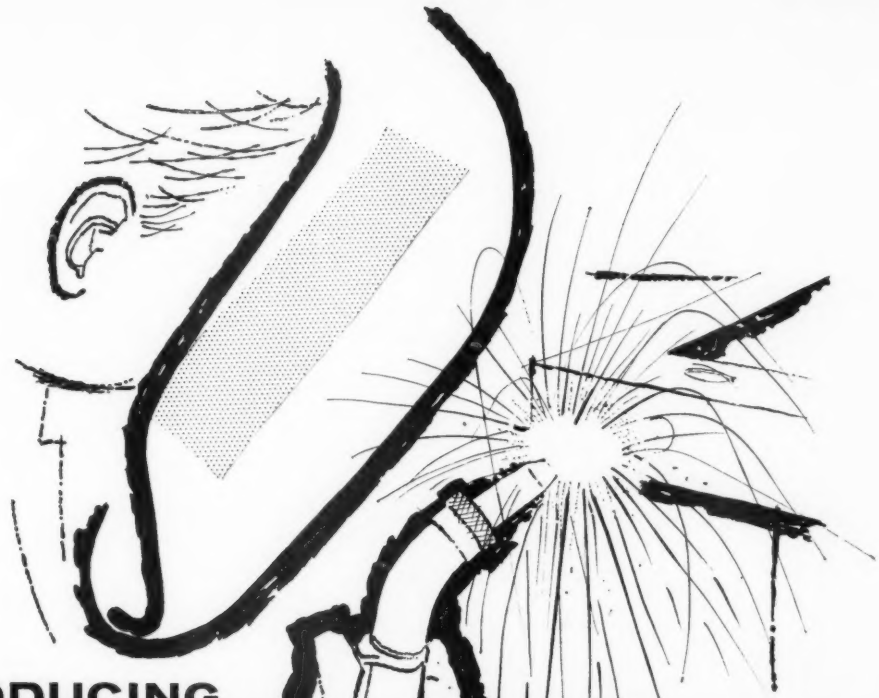

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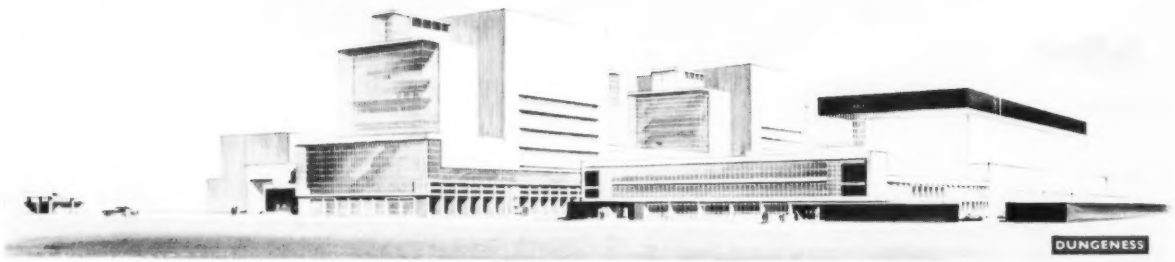

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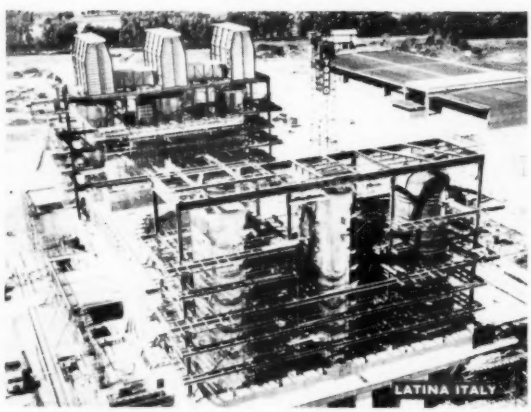
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